A–Z

the soviet encyclopedia of space flight

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Mankind will not stay on the Earth forever, but in hunting for light and space will first escape from the atmosphere and then occupy the whole near-Sun space.

K. E. TSIOLKOVSKY

A highly reliable and efficient rocket engine is required in the first place for attainment of success.

All efforts should be directed to the development of the rocket engine.

S. P. KOROLEV

The Moon is not too distant a neighbour of ours. I think we'll not wait too long for flights to the Moon.

Yu. GAGARIN

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the soviet encyclopedia of space flight

Edited by a group of leading
experts in space
science and engineering

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Preface

The beginning of the second half of the twentieth century was marked by man's first space efforts. The millennial aspirations of man to reach the stars are coming true. The Soviet Union blazed the trail into space by launching the first man-made satellites of the Earth, the Sun and the Moon, the first automatic interplanetary stations to the Moon, Venus and Mars, and the first manned spaceships, both single-seaters and multi-seaters. A Soviet cosmonaut performed the world's first walk in open space. Soviet space stations were the first to reach the surface of the Moon and Venus, photograph the far side of the Moon, accomplish a soft landing on the Moon and transmit pictures of the lunar landscape to the Earth. The first trip round the Moon and back to Earth was accomplished by automatic versions of Soviet spaceships. The first men and the first woman to perform single and group flights in space were citizens of the Union of Soviet Socialist Republics.

The USSR became in 1957 the world's first space power, to be followed by the United States of America in 1958 and France in 1965. In the not distant future, the European Community, Great Britain and Japan will join the space club.

Outstanding successes have been achieved by the USA. Besides launching an imposing number of artificial Earth, Moon and Sun satellites of various designation, and exploration of Venus and Mars by automatic interplanetary stations of the fly-by type, the United States have completed their programme of Moon exploration by automatic stations and are making preparations for manned descent to the Moon. The manned flights round the Moon with subsequent return of the spaceships to the Earth are of historic significance.

Man's conquest of outer space is making rapid progress. By May 1, 1969, the Soviet Union alone put into orbits round the Earth, the Moon and the Sun 373 stations and spaceships with a total weight exceeding 1166 tons (2107 tons, counting the upper stages of the launch vehicles that went into the same orbits in space). Twenty seven stations weighing a total of 45 tons (72 tons, including the upper stages) were accelerated to approximately second cosmic velocity. Forty spacemen from the USSR and the USA have made flights in space. Though only twelve years have passed since *Sputnik-1*, the world's first artificial Earth satellite, heralded the beginning of the space age, space research and practical applications stemming from it have become part and parcel of our day-to-day life. Widespread interest in problems of space flight has given rise to the publication in recent years of encyclopedias and handbooks devoted to space science and technology in the USA, the German Democratic Republic, France and Spain.

The first encyclopedia of interplanetary travel was published in three volumes (9 books) in 1928—1932 in the USSR. It presented a large range of data compiled by its author, N. A. Rynin. In those years while this encyclopedia was being put out, many countries were making the transition from the theoretical studies started by K. E. Tsiolkovsky to laboratory tests. The first liquid-propellant engines were fired and the first liquid-propellant rockets were launched. Nearly thirty years of concentrated effort were needed to develop the cardinal element in rocketry—a powerful liquid-propellant engine with sufficiently high performance and reliability characteristics. The appearance of these engines opened the road to the development of rocket vehicles of various designation, capable of facilitating the exploration of outer space.

Contributors to the present *Encyclopedia of Space Flight* are Soviet specialists engaged in the development of space-rocket systems. The volume covers the main events in space research as of July, 1969. Special attention has been paid to the liquid-propellant rockets and engines that were originally outlined by K. E. Tsiolkovsky. They constitute the cornerstone of modern space technology. Such vehicles can be instrumental in the exploration and study of our entire solar system. In order to reach the outer planets within reasonable flight times, efficient liquid propellants capable of producing a specific impulse of 500 seconds are required; also necessary are interplanetary propellant depots for repeated in-flight refuelling, and *en route* gains in speed acquired by making use of the gravitation of the planets encountered. However, liquid-propellant rockets have limited potentialities for solving the problems of long-distance flight, which makes it imperative to boost the development of nuclear and electric rocket engines now under way in a number of countries. The appropriate combination of liquid-propellant, nuclear and electric engines within the rocket will yield vast potentialities for power generation and for a long time to come such rockets will be the chief vehicle used for travel within the solar system.

This *Encyclopedia* includes information dealing with:

space flight;
spacecraft;
rocket engines;
propellants;
flight control and space navigation;
dynamics of space flight;
space communication;
space centres;
space medicine and biology;

life support systems;
geophysics;
astronomy;
space law;
biographies of scientists and spacemen.

Much attention is given to the history of Soviet rocketry and to scientifically substantiated interpretation of historical facts.

The scope of the entries has been limited by the size of the book. For this reason also, it has not been possible to cover fully the fundamental principles of the theory of processes and design or the great number of different rocket systems that have been developed, and the biographies of many of those who have contributed to the advancement of space research. We hope to make up for this in further editions of the *Encyclopedia*.

The book has been written for a very broad range of readers. It will be helpful to scientists, teachers, students, inventors, popularizers of science, and to all those interested in the problems of space flight.

The *Encyclopedia* includes survey articles on the state of the art in each field of science and engineering covered by the book and reference articles defining the basic technology. All entries are arranged in alphabetical order. Alongside specialized terms, a reasonable number of articles concerning engineering in general is presented, e.g. SELF-CONTAINED SYSTEM, GAS ANALYSER, and RELIABILITY. However, because of the limited size and specific object of the present publication, these articles describe the respective terms from the viewpoint of space flight.

To facilitate use of the *Encyclopedia*, a list of abbreviations is given at the beginning of the book and a classified alphabetical index for each of the major subjects covered is given at the end.

A comprehensive bibliography of Soviet and foreign books published after the beginning of the space age (1957) is given in an appendix. To avoid repetition, all the references are given in a single list. There is also a list of the names of lunar features on the far side of the Moon and a table of data on all the spacecraft launched by the USSR and other countries as of May 1, 1969. Universal time is used in the table and local time in the articles.

As was to be expected, many difficulties arose in the course of compilation of such a complex work. Any comments from readers, which may help to improve further editions of this *Encyclopedia*, will be appreciated.

Professor G. V. PETROVICH
Editor-in-Chief

Latest breakthroughs in space are summarized on pp. 617—621.

List of abbreviations

ac	— alternating current
b.p.	— boiling point
CPSU	— Communist Party of the Soviet Union
dc	— direct current
dia	— diameter
GDL	— Gas Dynamics Laboratory
GDL—OKB	— Gas Dynamics Laboratory and Experimental Design Office
GIRD	— Group for Study of Reactive Motion
HF	— high frequency
IR	— infra-red
LOX	— liquid oxygen
LSS	— life support system
m.p.	— melting point
NASA	— National Aeronautics and Space Administration
RNII	— Rocket Research Institute
SHF	— super-high frequency
thou.	— thousand
TV	— television
USAF	— United States Air Force
UV	— ultra-violet
VHF	— very-high frequency

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ABLATION COOLING. A type of cooling of rocket engines or individual elements of a spacecraft subject to violent heating by a stream of hot gases. Ablation cooling consists in removal of heat for melting or sublimation of the material or a layer of a special substance applied to the heated surfaces. The products of sublimation move downstream and create a gas screen protecting the walls against direct contact with the gas (atmosphere, combustion products, working fluid).

ABSORBER. An apparatus for the removal of a substance from a fluid by solid bodies or liquids. It has found application in LSS. Depending on the type of the contact surface of the phases, absorbers are classified as surface, film, bubbling, and spray types. In weightless conditions the supply and removal of the liquid phase is a matter of difficulty; the force of gravity can be reproduced by an artificial field of force effected by rotation of the absorber unit as a whole or of some of its components. Use is also made of forced pumping of agents with subsequent separation of gases from liquids in centrifugal separators or in devices comprising selective elements. These devices, however, must be supplied with additional power. The service life and reliability of the unit as a whole are reduced due to rotary elements. Therefore it is preferable to employ in absorbers the effects of wetting and capillarity in porous hydrophilic elements.

ABSORPTION OF RADIO WAVES by the medium in which they travel depends upon the electrical properties of the medium and the wavelength (frequency). Absorption of radio waves occurs in the TROPOSPHERE at wavelengths of less than 5 cm (notably at wavelengths of 1.5 and 0.5 cm); it increases with a reduction in the angle of inclination of the antenna to the ground surface and during rainfalls. Ionospheric absorption of radio waves is observed only at wavelengths close to critical, whereas longer waves are fully reflected back to Earth. Thus, it is evident that radio waves shorter than 5 cm and longer than 3 m are not suitable for space communication.

ACCELERATING ENGINE. See SUSTAINER ENGINE.

ACCELERATION. A vector characterizing the magnitude and direction of change of velocity. The magnitude of an acceleration is directly proportional to the force acting upon the body and inversely proportional to its mass, while the direction of acceleration coincides with that of the force vector ($a = F/m$ where a is acceleration, F is force, m is mass). Acceleration is measured in m/s^2 or cm/s^2; sometimes acceleration is measured in relative units (g) that show how many times the given acceleration is greater than that of the force of gravity at the Earth's surface (9.81 m/s^2). Accelerations are differentiated according to duration (see LONG-TERM ACCELERATION; SHOCK ACCELERATION). In aerospace practice and medicine the terms "acceleration" and "g-force" are used interchangeably.

ACCELEROMETER. A space-borne instrument for measuring linear accelerations of a spacecraft. In INERTIAL NAVIGATION the accelerometer is one of the basic types of sensitive elements; generally, the spacecraft is provided with three accelerometers measuring linear accelerations at right angles to one another. A peculiar feature of the accelerometer is that it determines the APPARENT ACCELERATION of the spacecraft, rather than the true acceleration.

Acclimatization

ACCLIMATIZATION. Adaptation of man, animals and plants to new climatic conditions. When choosing organisms (animals and plants) for artificial ECOLOGICAL SYSTEMS, one must take into consideration their acclimatization capacities.

ACCRETION. The acquisition of matter from surrounding interplanetary space by a celestial body. The Earth's main form of accretion is the acquisition of meteoric matter which enriches the atmosphere with atoms of various metals, silicon, etc., and with meteoric dust that gradually settles on the surface of the Earth. The accretion of gases by the Earth's atmosphere is apparently not high though the capture of SOLAR WIND protons during the aurorae influences the distribution of hydrogen in the UPPER ATMOSPHERE. The process opposite to accretion is called DISSIPATION of atmosphere.

ACCURACY OF PROPELLANT LOADING. The degree to which the quantity of propellant loaded into the launch vehicle tank approximates the rated quantity specified for the flight mission. The accuracy of propellant loading is clearly determined by the error in loading, this error being of either a positive or negative value expressed in fractions of a per cent of the rated quantity of propellant. The error is due to inaccuracy of propellant metering devices, inertia of the propellant-loading control system, and the cut-off fittings. The device error in volume measurement is ± 0.5 to $\pm 0.1\%$, and in weight measurement ± 0.5 to $\pm 0.2\%$. The propellant loading error increases the emergency stock which, at the constant lift-off weight, reduces the payload.

ACOUSTIC LOAD. The effect of a high-intensity sound (acoustic) field originated during operation of a rocket engine on the spacecraft, machinery, instruments, and buildings of the launch complex and the personnel. The acoustic energy generated by the efflux of the rocket engine (generation of the acoustic field takes up to 1% of the kinetic energy of the efflux) is characterized by a broad frequency spectrum and may cause resonant vibrations of the structures and their elements. The equipment, instruments and elements of control systems are particularly sensitive to the acoustic loads. The acoustic load can also cause injuries to the personnel. The quantitative estimation of the acoustic load includes such parameters of the acoustic field as sound pressure level, frequency spectrum, and duration of action. This estimation helps to specify the characteristics of the equipment and instruments and the methods of their testing, as well as to select adequate protection and distances at which the equipment, instruments, and personnel will be safe.

ACTINOMETRIC INSTRUMENTATION of meteorological satellites. Instruments on board meteorological satellites for measuring the components of the Earth's heat balance. The *Cosmos-122* meteorological satellite carries actinometric instrumentation sensitive to the following regions of the spectrum: 0.3—3 μ, 8—12 μ and 3—30 μ, which permits measurement of the EARTH ALBEDO RADIATION and EARTH RADIATION. The *Tiros* satellite carries a 5-channel radiometer sensitive to bands 6.0—6.5 μ, 8.0—12.0 μ, 0.2—6.0 μ, 8.0—30 μ and 0.55—0.75 μ. Data of measurements in the 8—12 μ atmospheric water vapour windows permits solving the problem of determining the temperature of the underlying surface or the temperature and the height of the upper cloud boundary.

ACTION OF JET EFFLUX. The mechanical, thermal, erosive, chemical and other effects of the engine jet efflux on ground equipment during the launch and initial period of flight above the launching pad. The high-temperature supersonic jet of a single rocket engine or cluster of engines produces a marked mechanical and thermal effect on the launch system. For example, the mechanical load applied to the surface of the flame deflector depends upon the distribution of the jet pressure over the surface; the maximum pressure may reach several at. The maximum force applied to a large-size barrier placed perpendicular to the axial flow of the jet does not exceed the engine thrust. The thermal action of the jet efflux is characterized by the maximum temperatures of, and the thermal fields in, the walls of the gas baffle and other structural elements of the launcher. As a result, the metal of the walls begins to melt, is burnt through, ablates, etc.

ACTIVATED CARBON. Carbon obtained from vegetable matter (usually charcoal) and subjected to special treatment. Used in the LSS for reactivation of air and water, for absorption of noxious impurities, in filters, etc.

ACTIVE RELAY STATION (repeater). A radio transmitter-receiver provided at a moving or fixed point of a radio communication line for the reception, amplification and further transmission of messages from an intermediate or terminal point to another point on the line. Active relay stations mounted on a COMMUNICATIONS SATELLITE incorporate a radio receiver, a separator (for separating the commands and telemetry signals), a radio transmitter and a supply source. A common antenna and an electric filter for preventing mutual interference may be used for simultaneous reception and transmission of messages carried on different, but neighbouring, wavelengths. The space-borne equipment of active relay stations uses semiconductor circuit elements; special SHF radio valves (travelling-wave valves and others) with a power of several tens of W are used in the radio transmitter.

ACTIVE SLUDGE. A biological community of mineralizing microorganisms and certain species of protozoa, which effect biochemical oxidation of organic materials in the aerotanks of spacecraft LSS. The active sludge is formed on the basis of environmental microflora. The organic matter of active sludge consists chiefly of proteins, owing to which the sludge can serve as the food for HETEROTROPHIC ORGANISMS.

ACTIVE SYSTEM OF ORIENTATION. A system of orientation according to which the control torques orienting the spacecraft are produced by flight control elements energized from power sources on board. The main types of control elements used are ATTITUDE CONTROL MOTORS, INERTIAL ACTUATORS and ELECTROMAGNETIC ACTUATORS. Unlike passive systems of orientation, an active system of orientation is capable of overcoming a considerable DISTURBING MOMENT (provided the flight control elements have adequate capacity) and permits changing of the controlled position of the spacecraft, i.e., provides for PROGRAMMED ROTATION in space; at the same time, active orientation involves energy consumption and, therefore, its service life is shorter than that of a passive system of orientation.

ACTIVITY SPHERE OF MOON. A sphere described from the centre of the Moon by a radius of about 66,000 km, inside which the ratio of acceleration imparted to a celestial body by the Moon to the perturbing acceleration impar-

ted to the body by the Earth is greater than the ratio of acceleration imparted to the celestial body by the Earth to the perturbing acceleration due to the Moon. When studying the motion of a spacecraft within the activity sphere of the Moon, it is preferable to regard the Moon as the central body and the Earth as the perturbing body. When a spacecraft is in motion outside this sphere, it is best to regard the Earth as the central body and the Moon as the perturbing body.

ACTIVITY SPHERE OF PLANET. A sphere described from the centre of a planet by a radius equal to $R = r\left(\frac{m}{m_0}\right)^{2/5}$ where r is the distance of the planet from the Sun, m is the mass of the planet, and m_0 is the mass of the Sun. The property of this sphere is that within it the ratio of acceleration imparted to a celestial body (e.g., a spacecraft) by the planet to the perturbing acceleration due to the Sun is greater than the ratio of acceleration imparted to this body by the Sun to the perturbing acceleration due to the planet; conversely, outside the activity sphere of the planet, the latter ratio is greater than the former. Therefore, when a body moves inside the activity sphere of a planet it is preferable to regard the planet as the central body and the Sun as the perturbing body. Contrariwise, when a body moves outside this sphere, it is preferable to regard the Sun as the central body and the planet as the perturbing body.

Radii of activity spheres of planets (10^6 km):

Mercury 0.14	Jupiter 48
Venus 0.62	Saturn 54
Earth 0.94	Uranus 51
Mars 0.63	Neptune 87

ACTUATORS of flight control system. The devices thate creat the steering forces and controlling moments applied to a spacecraft. The actuators are controlled by sensing elements of the system and driven by converting devices.

ADAPTATION. The process of human, animal and plant adjustment to changing environmental conditions. During a space flight this process takes a specific course. Thus, man shows pronounced alterations of sensor afferentation (perception and transmission of stimuli to the central nervous system), as well as changes in the interaction of analyzers. Adaptation is of special importance in solving problems of the effect of isolation and monotonous surroundings on man during extended space flights, and, particularly, in creating an atmosphere of positive emotions, in increasing working capacity, in improving the power of concentration and redistribution of attention, and in adjustment to new conditions of work and rest. General physical training is a major factor in adaptation; its part is especially important in selection and training of pilots and spacemen.

ADDITIVES for propellants. Small quantities of various substances added to rocket propellants to impart the properties desired, e.g., increased stability (STABILIZERS), inhibited corrosive action on metals (INHIBITORS), a lower melting point of liquid components, better pumpability, increased reactivity of the components (improved ignition, uniformity, stability, and completeness of combustion), or, on the contrary, decreased reactivity, etc.

ADSORBER. An apparatus for extraction of evaporized and gaseous contaminants from the air in sealed spaceship cabins. Operation of the apparatus is based on adsorption of substances removed by the surface of highly porous substances, or adsorbents, such as various types of silica gels, synthetic zeolites and activated carbons. To ensure continuous air decontamination and desiccation, two parallel adsorbers are operated in sequence as adsorber and desorber (to regenerate the sorbent).

AERODYNAMIC DRAG. The aerodynamic force acting upon a body in motion through the air or some other gas and decelerating the motion of this body. The value of aerodynamic drag is proportional to the velocity pressure, cross-section area, and drag coefficient which depends on the body's shape, MACH NUMBER and ANGLE OF ATTACK.

AERODYNAMIC HEATING. Heating of the surface of a spacecraft, launch vehicle or re-entry body during motion through the atmosphere. It becomes noticeable during flight at supersonic speed and is due to conversion of the kinetic energy of the vehicle retarded by the atmosphere into the thermal energy of the gas which flows around the vehicle and, in turn, transfers part of the heat to the surface of the vehicle. The gas is heated in PRESSURE SHOCKS and in the boundary layer near the wall, where its flow is decelerated relative to the surface of the moving vehicle. The thermal energy of the completely decelerated gas is characterized by the impact temperature which in some instances becomes very high. Thus, when a vehicle moves at the first cosmic velocity in the Earth's atmosphere, its impact temperature, considering partial energy loss on dissociation, is as high as 6000°—8000°K. The heat from the gas is transferred to the vehicle's external surface by convection and radiation.

AERODYNAMIC LOADS. Loads acting on structural elements of a spacecraft, rocket or re-entry body and developing under the action of aerodynamic forces during motion through the atmosphere. Aerodynamic forces appear in the form of distributed forces of pressure and friction. During the POWERED FLIGHT PHASE the aerodynamic loads first increase with acceleration and reach a certain maximum (usually at an altitude of 10—12 km), and then decrease practically to zero when the rocket passes beyond the dense atmospheric layers. For a re-entry body, aerodynamic loads are greatest when the body enters the dense atmospheric layers at the height of several score km. Aerodynamic loads are, as a rule, accompanied by AERODYNAMIC HEATING of structural elements.

AERODYNAMIC MOMENT. The moment acting on a RE-ENTRY BODY moving in the atmosphere, due to which the longitudinal axis of the body assumes a definite position with respect to the gas counter-flow. The ANGLE OF ATTACK of the re-entry body, which in this position is referred to as its angle of aerodynamic trim, is selected depending on the required LIFT FORCE.

AERODYNAMIC QUALITY. See LIFT/DRAG RATIO.

AERODYNAMIC STABILITY. The ability of a spacecraft, rocket or re-entry body to resume its original position during space flight (relative to velocity vector) under the action of aerodynamic forces. It occurs when the centre of action of the resultant aerodynamic forces (so-called centre of pressure) is

behind the vehicle's centre of mass. The distance between the centre of mass and the centre of pressure (usually expressed in percentage of total vehicle length measured along its longitudinal axis) characterizes the margin of static stability. Dynamic stability is ensured by the damping properties of the vehicle, determined by its aerodynamic characteristics which, in turn, depend on its shape and balance.

AEROPONICS. Cultivation of plants without soil by nebulization of nutrient solutions in the rhizogenous zone. Aeroponics requires smaller amounts of nutrient solutions as compared with other methods of cultivation. This method has not been thoroughly studied as yet, and is rarely employed. If properly developed, aeroponics may be practicable in the LSS, owing to its weight characteristics.

AEROSENE-50. A liquid rocket fuel widely used in the USA, consisting of a mixture of 50% (by weight) unsymmetrical DIMETHYL HYDRAZINE and HYDRAZINE. Density ~0.9 at 21°C, b.p. 70°C, m.p.—7.3°C.

AEROSPACE PLANE. A new type of manned spacecraft, with a lifting surface (usually, a wing) designed for flight in the atmosphere and outer space. It combines features of both an aircraft and a space vehicle. The aerospace plane is a re-usable vehicle; it must be able to take off from airfields, accelerate to orbital speed, fly in space, and return to Earth by landing on an airfield. One of the main purposes of the aerospace plane is to serve as a space ferry, i.e., to supply MANNED ORBITAL STATIONS and to replace their crews. Re-usability will render the aerospace plane more efficient and economical than modern launch vehicles. Possible military applications of the aerospace plane are being investigated in the USA. It will probably be powered by a combination consisting of an air-breathing jet engine for flight in the atmosphere and a liquid-propellant engine for flight in the outer space (see AIR-BREATHING ROCKET ENGINE). The possible use of nuclear powerplants is also under study. Research is being conducted into several complex problems connected with the creation of the aerospace plane, and some projects are underway for development of aerospace planes with a take-off weight of several hundred tons (e.g., *Astro* in the USA, *Mustard* in Great Britain).

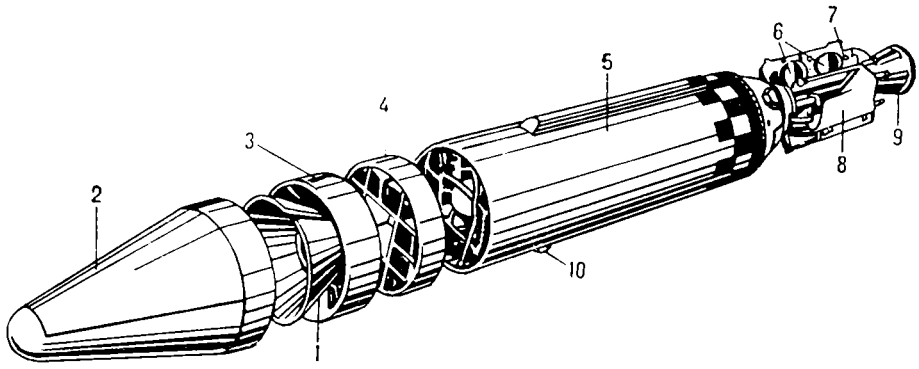
AEROTANK. A through-flow vessel in which the mixture of liquid wastes and activated sludge is aerated to achieve biochemical oxidation (mineralization) of organic matter of the liquid wastes and formation of mineral salt solutions and carbon dioxide. Mechanically aerated aerotanks may possibly be used in spaceship LSS for MINERALIZATION of wastes. The solution of mineral salts and carbon dioxide obtained in the tank may be utilized by higher and lower AUTOTROPHS. The increment of the activated sludge biomass, rich in proteins and vitamin B_{12}, may be used as food for HETEROTROPHIC ORGANISMS.

AFTERBURNER. A device for burning additional fuel in the exhaust pipe of a TURBOJET ENGINE in order to increase its thrust. The efficiency of afterburners increases with the speed of flight. The feasibility of using turbojet engines with afterburners on AEROSPACE PLANES is under consideration.

AFTERBURNING. (1) Burning of exhaust gases of the turbopump unit in the combustion chamber of a liquid-propellant engine. (2) Irregular bur-

ning of propellant in a liquid-propellant engine after the engine cut-off, i.e., after the propellant feed is discontinued. (3) Firing of additional fuel in the AFTERBURNER of a turbojet engine to augment its thrust. (4) Firing of combustion gases (combustion products of a propellant with an excess of fuel) in a jet stream by injecting atmospheric air into it (AIR BOOSTING).

AGENA. An upper stage used in some US launch vehicles (*Atlas-Agena*, *Thor-Agena*, etc.). It is capable of prolonged space flights with engine cut-off and re-starting; it weighs about 7 t propellant included and fires nitric acid



Agena rocket.

1—cone for joining the rocket to *Gemini*; spaceship; *2*—nose cone (jettisoned after launching); *3*—adapter; *4*—equipment compartment; *5*—propellant tanks; *6*—nitrogen bottles of orientation system; *7*—orientation system nozzles; *8*—auxiliary rocket system for correcting flight path at orbital approach; *9*—restartable sustainer rocket engine; *10*—vertical plotter of orientation system.

and unsymmetrical dimethyl hydrazine. The liquid-propellant engine of *Agena* delivers a thrust of 7.2 t. *Agena* has been used in experiments of orbital approach and docking (see GEMINI).

AGREEMENT *on the Principles of Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies*, signed on January 27, 1967 (depository states USSR, USA, UK), states that the exploration and use of outer space, including the Moon and other celestial bodies, are aimed at the welfare and are in the interests of all countries irrespective of the degree of their economic or scientific development, since they are the property of all mankind (Art. I). The same article proclaims that outer space and the celestial bodies are open to all States without discrimination and on a parity basis. This provision is closely associated with Article II banning the national usurpation of celestial bodies or outer space. Intimately connected with this is the principle that activities in space should conform with international law, including the UN Charter, in the interests of maintaining international cooperation and mutual understanding (Art. III).

Among the restrictions associated with activities in outer space deserving of mention is the primary obligation of states not to launch into space any objects carrying nuclear weapons or other means of mass annihilation (Art. IV). The agreement bans not only testing of nuclear weapons in outer space, but also their injection by any means. According to the same article, the Moon and other celestial bodies shall be used exclusively for peaceful purposes, and establishment of military bases, structures or fortifications,

Agreements on joint satellite launchings

testing of any types of weapons, and military manoeuvres there are prohibited. For practical reasons, there is a provision allowing the use of military personnel and any suitable equipment for peaceful research.

The Agreement establishes the general principle of the international responsibility of the participant states for national activity in outer space, whether it is carried out by governmental authorities or non-government juridical persons (Art. VI), as well as the liability for damage caused by space objects or component parts thereof to another member state, its physical or juridical persons, irrespective of whether the damage was done on the Earth, in the air, or in outer space (Art. VII).

The Agreement imposes on the states the obligation to exercise particular caution with regard to conducting space experiments which may interfere with the activities of other states or adversely affect the terrestrial atmosphere (Art. IX).

Cooperation in the peaceful exploration of outer space may take place both on Earth and in space. It is evident that problems of cooperation in outer space have not acquired acute practical significance as yet, but the Agreement envisages certain obligations in this field as well: spacemen of one state should render every possible aid to spacemen of another state on mission in outer space or on celestial bodies (Art. V); all stations, plants, equipment and spaceships on the Moon and other celestial bodies are open to representatives of other member states (Art. XII).

With a view to promoting international cooperation, the member states agree to inform the UN Secretary General, as well as the public at large, as far as possible and practicable, of the nature, progress, location and results of their activities in outer space (Art. XI), as well as to inform other member states or the UN Secretary General of phenomena in outer space which may endanger the life or health of spacemen (Art. V).

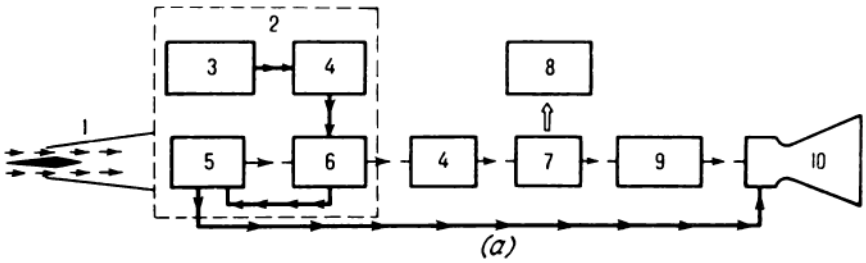
AGREEMENTS ON JOINT SATELLITE LAUNCHINGS AND SPACE RESEARCH. Several agreements have been concluded between the USA and a number of other countries, as well as within the framework of European organizations for space research (ESRO, ELDO, etc.) and agreements between ESRO and the USA. Most of the agreements (except for the agreement between the USSR and the USA) have been prompted by the necessity to overcome the lack of economic resources, engineering and research facilities experienced by individual countries in the development of their own space programmes. However, in a number of instances the agreements are motivated by the fact that certain problems are more effectively solved by international co-operation. One example is the agreement to set up a world-wide geodetic network, signed by the International Association of Geodesy, COSPAR, the International Union of Geodesy and Geophysics, and other organizations; and the agreement drawn up in 1966 between the USSR and France on cooperation in the exploration of outer space.

Other examples of international cooperation are the joint observations of satellites, conducted in the socialist countries according to a unified program using standardized equipment, and the European satellite observation program INTEROBS providing for the observation of satellites for geodetic purposes.

In 1964 the countries of Europe, Asia, America, and Australia signed a convention on regulation in global commercial satellite communication systems. The widest form of international co-operation in space exploration and research is participation in the work of the INTERNATIONAL ASTRONAUTICAL FEDERATION, COSPAR, and other international unions and organizations which, as a rule, have a number of special committees. It is the opinion of the Soviet government, as well as of a number of other governments, that the exploration and research of space and celestial bodies should be carried out according to a definite set of judicial principles formulated by international agreement as the legal basis for global cooperation (see also SPACE LAW).

AIR BOOSTING of rocket engine. The increase of the thrust and specific impulse of a rocket engine by inducing atmospheric air into the jet stream to increase its mass or for AFTERBURNING of the products of combustion of a propellant with excess fuel. Though repeatedly suggested, it has not been employed.

AIR-BREATHING ROCKET ENGINE. A combined reaction engine which operates as an air-breathing jet engine and as a rocket engine. In space flight



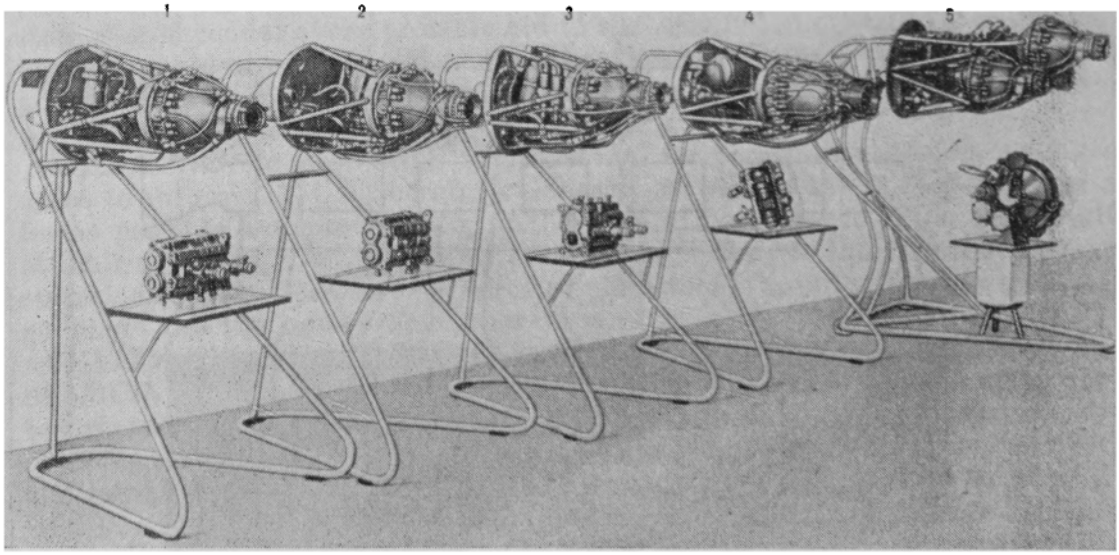
Air-breathing rocket engine: (*a*) schematic diagram of an air-breathing rocket engine burning liquid hydrogen in liquefied atmospheric oxygen; (*b*) transfer of liquefied atmospheric oxygen from orbiting spacecraft equipped with air-breathing rocket engine into spaceship.

1—hypersonic air intake; *2*—air liquefaction unit; *3*—liquid hydrogen; *4*—pumps; *5*—preliminary coolant; *6*—condenser; *7*—separator; *8*—liquid nitrogen; *9*—oxygen-rich liquid air; *10*—thrust chamber.

it may be used for propelling AEROSPACE PLANES. Sometimes this name is given to an engine which uses atmospheric air liquefied in flight as an oxidizer. A similar hypothetical engine has been suggested for prolonged flights in the upper layers of the atmosphere.

AIR CONDITIONING. Automatic maintenance of designed atmospheric parameters (pressure, temperature, humidity, and composition) in a spaceship's sealed cabin, as well as ventilation of the cabin and air scrubbing to remove noxious contaminants and provide comfort conditions for the crew. The air conditioning systems are incorporated in the LSS.

AIRCRAFT ROCKET ENGINE. A rocket engine for mounting on aircraft. Solid-propellant rocket engines are used as take-off assists, whereas re-startable liquid-propellant engines with thrust control are used for assisting take-off, manoeuvring in flight, or as the main engines. The first aircraft rocket engines in the USSR were the *Д1-А-1100* and the family of *РД-(1—3)* engines.



Aircraft rocket engine (of GDL-OKB design):

1—*РД-1*, thrust 300 kg; *2*—*РД-1Х3*, thrust 300 kg, chemical ignition; *3*—a version of the *РД-1Х3* for another aircraft; *4*—*РД-2*, thrust 600 kg; *5*—*РД-3*, thrust 900 kg, three chambers, fitted with turbopump unit. Shown under the engines are pump units.

AIR DESICCATION in spaceship. The reduction of humidity in the sealed cabin to comfort condition. Air desiccation may be effected by chemical, physico-chemical or physical methods. The chemical methods involve absorption of water vapours by desiccants and the formation of new compounds or crystallohydrates. Physico-chemical methods involve the use of various sorption and chemosorption processes; the physical methods are based on cooling the air to a temperature at which condensation of water vapours

begins and a liquid or solid (ice) phase is formed; diffusion and other processes may be also used. Air is usually desiccated with solid desiccants which may be natural (gels) or impregnated (sorbent). The desiccation of air with gels (such as silica gel, alumogel, ferrogel, activated charcoal, zeolites) is effected by adsorption with subsequent capillary condensation of moisture in the pores. The impregnated desiccants used are made of porous materials (carriers) whose surface is covered with a thin layer of a hygroscopic substance. The air moisture is absorbed by this layer and also removed by capillary condensation of moisture in the carrier pores.

AIR HEATER. A mobile or stationary plant used for heating air and supplying it to various sections of the launch vehicle and launcher so as to maintain required temperature conditions. This plant comprises a heating device, air blower, and control unit. The heating device incorporates electric heating elements over which cold air is passed or, alternatively, a special gasoline-fired brazier whose external surface is washed by the cold air. The maximum temperature of the heated air is 120°C.

AIR IONIZATION. Artificial increase in the concentration of aeroions, usually negatively charged (anions), in the atmosphere of the spaceship cabin to make it more comfortable. The hygienic criterion that determines the quality of the aerial environment is the unipolarity coefficient, i.e., the ratio between the number of aerocations and aeroanions. It should be 0.7 to 0.8 in sealed cabins. Air ionization is achieved by means of electric ionizers.

AIR-LOCK COMPARTMENT. A special airtight compartment for exit of spacemen from the spacecraft during flights without necessarily de-pressurizing the crew cabin. The air-lock compartment is provided with two airtight quick-release hatches one of which opens into the cabin of the spacecraft and the other, into outer space. After the spaceman (in space suit) has entered the air-lock compartment from the capsule, the air is released from this compartment and then the spaceman leaves the spaceship through the outer hatch. On his return to the spaceship, the spaceman re-enters the air-lock compartment and, after the outer hatch has been closed, its pressure is brought up to that inside the cabin. After this, the spaceman enters the cabin through the inner hatch. An air-lock compartment was provided on the *Vostok-2* spaceship for the exit of the cosmonaut A. A. Leonov into outer space.

AIR SEPARATION UNIT. An installation included in the gas supply station of a space centre and intended for producing gaseous nitrogen by rectifying liquefied air. It comprises a heat-insulated casing accommodating a liquid nitrogen pump, a rectifying column (single-rectification separator for fractionating the air into liquid nitrogen and waste gas), a liquefier (heat exchanger that cools the air before the desiccation unit to condense moisture and oil), adsorbers (containers filled with silica gel and intended to clean the air of carbon dioxide and acetylene), a recuperative heat exchanger and a heat exchanger to cool the air from the gas expander to —150°C and —168°C, a liquid nitrogen supercooler, filters for cleaning gases of mechanical impurities and, finally, an instrument panel.

AIR THERMOSTATIC CONTROL. The maintenance of a pre-determined temperature under the space vehicle fairing in order to keep the temperature of the instruments and propellants in the tanks of the vernier motors and

retro-rocket at a definite level. As a rule, the air thermostatic control system operates from the moment the space vehicle is installed on the launcher till launching. Sometimes it is energized when the space vehicle leaves the assembly building. Double-loop systems are commonly used. Circulating in the first loop is an intermediate heat-transfer agent, e.g., a solution of calcium chloride, that is cooled or heated in the heat exchanger of a heater-refrigerator. The solution, in turn, passes through a special heat exchanger that cools or heats the air circulating in the open second loop, which is used for the space vehicle thermostatic control. The air is circulated in the second loop by air blowers.

ALBEDO. The ratio of the radiative flux scattered by a surface element in all directions to the flux incident on the element. Albedo is a measure of reflectivity of a surface; the higher the albedo, the brighter the surface. For instance, the albedo of the Moon is 0.07, i.e., the lunar surface scatters in all directions 7% of the incident radiation and absorbs 93%. The higher the albedo of the rocket-skin, the less it is heated by solar rays.

ALDRIN, Edwin E., Jr. (born 1930, Montclaire, N.J.). US astronaut. USAF colonel. Graduated from the US Military Academy in 1951, and the Massachusetts Institute of Technology in 1963. Served with the US Air Force as pilot and aerial gunnery instructor. Graduated from the Squadron Officers School of the Air University. Participated in the development of the *Gemini* program. Joined the group of astronauts of the NASA in 1963. He was co-pilot on an orbital flight made with J. Lovell in the *Gemini-12* spaceship on November 11—15, 1966; they circled the Earth 59 times in 94 h 30 min.

ALLELOPATHY. Reciprocal influence of organisms, particularly, higher plants, caused by physiologically active volatile and water-soluble excretions. Allelopathy can play an important role in spaceship BIOTECHNICAL SYSTEMS. In spaceship closed systems for RECYCLING OF SUBSTANCES, multi-directional allelopathy is possible; this is reciprocal action between vegetable organisms, their influence on animal organisms and man, and the influence of the latter on plants.

ALTITUDE (in astrometry). A coordinate in the horizontal system of CELESTIAL COORDINATES; the angular height of a celestial body above the plane of horizon; measured in the range of 0° to 90°.

ALTITUDE-FREQUENCY RESPONSE of the ionosphere. See IONOSONDE.

ALTITUDE OF APOGEE. The distance of the APOGEE of the Moon, an artificial Earth satellite or any other celestial body from the surface of the Earth.

ALTITUDE OF APOLUNE. The distance of the APOLUNE of an artificial lunar satellite or any other celestial body from the surface of the Moon.

ALTITUDE OF PERIGEE. The distance of the PERIGEE of the Moon, an artificial Earth satellite or any other celestial body from the surface of the Earth.

ALTITUDE OF PERILUNE. The distance of the PERILUNE of an artificial lunar satellite or any other celestial body from the surface of the Moon.

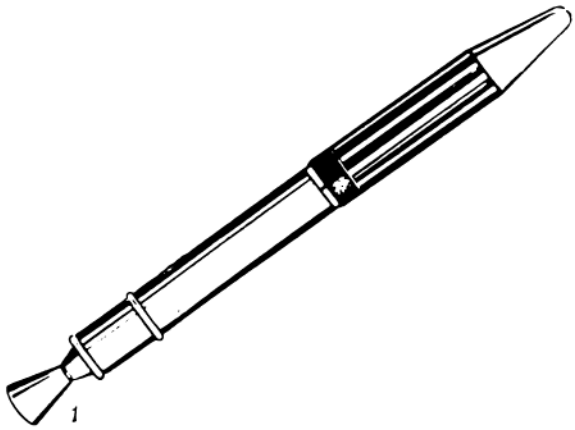
ALTITUDE SICKNESS (mountain sickness). A pathological condition developing at high altitudes due to reduced partial pressure of oxygen in the

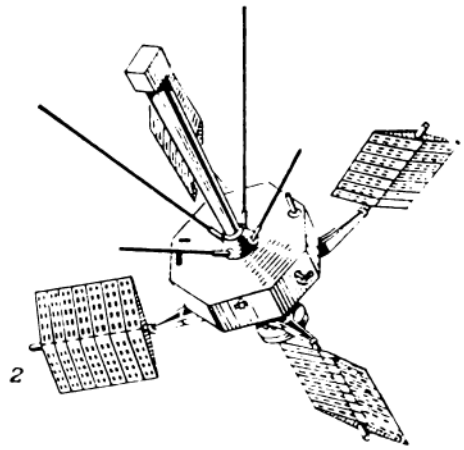
air inhaled. The chief symptoms of altitude sickness are dyspnoea, tachycardia, vertigo, tinnitis, headache, muscular weakness, excessive perspiration, disturbance of vision acuity, drowsiness, deterioration of working capacity, nausea, etc. The development of altitude sickness may be prevented by oxygen inhalation. The training program for spacemen should include mountain climbing, swimming and skin diving as sports that increase resistance to oxygen deficiency.

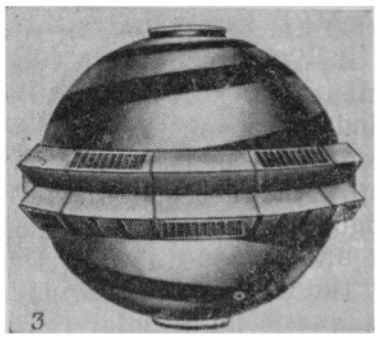
American Earth satellites

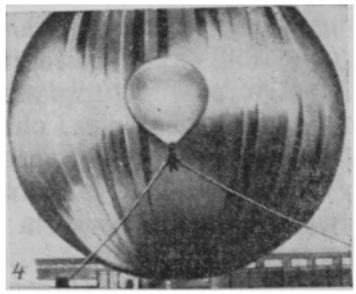
AMERICAN EARTH SATELLITES. The USA launched its first Earth satellite, *Explorer-1*, on February 1, 1958. It weighed 8.3 kg (14 kg, including upper stage of launch vehicle), had a dia of 15 cm and was not oriented in flight. The satellite's equipment operated for 27 days. Between 1958 and January 1, 1969, the USA launched some 550 Earth satellites of various types. A large number of US satellites are light in weight (under 100—200 kg), though some weigh as much as 3—4 t. The orbital block of the *Apollo-4* spaceship launched in November, 1967, weighed ~23.5 t, while the maximum payload injected into orbit by the *Saturn-5* launch vehicle (including 3rd stage of rocket) was ~127 t. In a number of cases several satellites (as many as 8) were sent to neighbouring orbits by one launch vehicle. US satellites orbit at altitudes of ~135 km to ~494,000 km (*Explorer-33*); some are in synchronous orbits (*Syncom*, *Early Bird*, *ATS*, etc.). Most US satellites do not have a sealed capsule, their equipment being designed to operate in vacuum. Electric power supply is provided by various types of space-borne systems, *viz.*, solar batteries, chemical sources, and fuel cells. Nuclear-isotope batteries have also been used. Certain unmanned Earth satellites, e. g., *Discoverer*, *Samos*, and *BIOS*, and all spaceships comprise capsules which, after the orbital flight, perform re-entry and splash-down in the ocean.

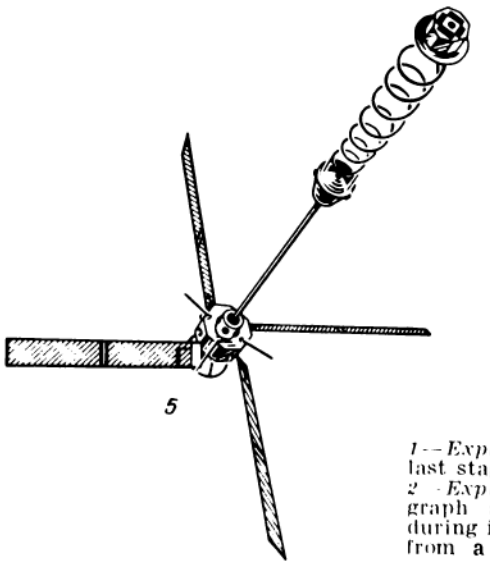
The main research satellites launched by the USA are the *Vanguard* (3 launched in 1958—59 for investigation of magnetic field, solar radiation, and micro-meteorites; weight: 1.5—23 kg; maximum apogee: 3970 km); *Explorer* (weight: 7—220 kg; apogee: 870—494,000 km; mission: study of radiation belt, magnetic field, properties of atmosphere and ionosphere, cosmic rays, micro-meteorites, etc.; some have attitude control systems); *OSO* Orbital Solar Observatory (weight: 208—272 kg; apogee: up to 630 km; oriented towards Sun with high accuracy); *OGO* Orbital Geophysical Observatory (weight: 487—610 kg; orbits: circular at altitude of ~1000 km or elliptical with apogee up to 150,000 km; attitude controlled); *OAO* Orbital Astronomical Observatory (weight: 1770—2000 kg; orbit: circular at altitude of ~800 km; equipped with high-accuracy system of astro-orientation); *OV* (weight: 9—270 kg; apogee: from a few hundred km to 111,000 km; some *OV* satellites are supplementary payloads of other Earth satellites); *ATS* (missions: development and testing of space-borne equipment, experiments in long-range communication, TV relaying, etc.; weight, including solid-propellant engine: 700 kg; orbital weight: 350 kg; orbit: stationary; orientation: by spin and gravity); *Pegasus* (3 launched in 1965 to investigate meteoric particles; weight: 1.45 t; apogee: up to 740 km; equipped with folding panels carrying transducers, span 29.3 m); *ERS*, the smallest spacecraft launched by the USA (weight: up to 0.7 kg). The *BIOS* biological satellite weighs 495 kg, including 245-kg re-entry capsule 1 m in dia; thus far its











Earth satellites launched by USA

1—*Explorer-1*, weight 5.6 kg (weight together with last stage of launch vehicle 13.8 kg), diameter 15 cm; *2*—*Explorer-14*; *3*—*Transit-1B*; *4*—*Echo-II* (photograph shows the sphere in the inflated condition during inspection by an operator in a cage suspended from a balloon); *5*—satellite with a gravitational orientation system.

orbital life-time has not exceeded 2 days, but it is planned to launch these satellites with monkeys on board for up to 30 days. The meteorological satellites sent up by the USA include: *Tiros* (weight: 120—131 kg; apogee: 970—2580 km; stabilization: by spin; carries 2 TV cameras); *ESSA* and *NIMBUS*. Among the communication satellites are *Telstar* (weight: 80 kg; apogee: up to 10,800 km; stabilization: by spin; mission: TV relaying); *Syncom* (3 launched into synchronous orbits at altitudes of 34,000—36,000 km; weight, including solid-propellant engine: 67 kg; orbital weight: ~40 kg); *Early Bird* (weight: 68 kg; orbit: stationary; is part of the *INTELSAT* system); *Echo* passive communications satellite (2 launched; inflated balloons of aluminium-coated Mylar film 30 or 41 m in dia; weight: 68 or 256 kg; apogee: up to 1700 km). Geodetic and navigational satellites are: *Transit* (weight: 60—120 kg; apogee: 700—1100 km; mission: aid in air and sea navigation); *Secor* (weight: 18 kg; flight altitude: 1000—3700 km; mission: geodetic measurements); *ANNA* and others. The data on the missions and characteristics of a great many US satellites are not disclosed, probably due to their military designation. By January 1, 1969, these so-called "secret satellites" numbered 250; they were injected into orbits with perigees of 130 km and over, and apogees of 250 to 3700 km; unofficial press reports indicate that they include *Discoverer* and *Samos* reconnaissance satellites carrying photo equipment.

AMERICAN ROCKET ENGINES. The creation of liquid-propellant engines in the USA was pioneered by R. Goddard beginning 1923. The development of liquid-propellant rocket engines in the USA reached its greatest scope after World War II. A powerful rocket industry has been created and a large variety of liquid-propellant and solid-propellant engines designed. Extensive research is being conducted in this field. The main liquid-propellant engines designed for space flight: Bell *XLR 81-BA-9* (thrust, 7.25 tons; specific impulse in vacuum, 300 s; burning time, 240 s; weight, 136 kg; diameter, 900 mm; chamber pressure, 36 at; propellant, nitric acid + unsymmetrical dimethyl hydrazine; designed for the *Agena* launch vehicle); *Pratt & Whitney RL10A-3* (thrust, 6.8 t; specific impulse in vacuum, 433 s; burning time, 475 s; weight, 132 kg; diameter, 1010 mm; chamber pressure, 20.5 at; propellant, LOX + liquid hydrogen; designed for a stage of the *Centaur*); the most powerful US liquid-propellant engine is the *Rocketdyne F-1* (thrust, 680 t; specific impulse in air, 260 s; burning time, 150 s; weight, over 8 t; chamber pressure, 63 at; propellant, LOX + kerosene; designed for the first stage of the *Saturn-5* launch vehicle which is a cluster of 5 such engines); *Rocketdyne J-2* (thrust, 90.7 t; specific impulse in vacuum, 422 s; burning time, 500 s; weight, 1580 kg; diameter, 2000 mm; chamber pressure, 45 at; propellant, LOX + liquid hydrogen; designed for 2nd and 3rd stages of the *Saturn-5* launch vehicle); *Rocketdyne H-1* (thrust, 85—93 t; specific impulse in vacuum, 285 s; burning time, 160 s; weight, 878 kg; diameter, 1240 mm; chamber pressure, 42—45 at; fires a LOX + + kerosene propellant; designed for 1st stages of the *Saturn-1* and *Saturn-1B* launch vehicles. Experimental liquid-propellant engines include: *Bell* (thrust, 1.6 t; specific impulse in vacuum, 336 s; chamber pressure, 8.5 at; fires nitrogen tetroxide + aerosene-50; designed to lift the *Apollo* space-

ship from the Moon); *Space Technology* (thrust, 4.76 t; chamber pressure, 7.7 at; burning time, 730 s; propellant, nitrogen tetroxide + aerosene-50; designed for landing the *Apollo* spaceship on the Moon); *Thiocol TD-339* (thrust, 13—48 kg; weight, 2.7 kg; fires nitrogen tetroxide + monomethyl hydrazine; serves as vernier engine of the *Surveyor* spacecraft), etc. Liquid-propellant engines using liquid fluorine as the oxidizer, nuclear rocket engines and electrical rocket engines are also being developed. The solid-propellant engines designed for space uses include the Alleghany *Antares-2* (thrust, 10 t; burning time, 36 s; weight, 1.2 t; dia, 760 mm; length, 2.9 m; to be used in the 3rd stage of the *Scout* launch vehicle); *Castor* (thrust, 28 t; burning time, 27 s; weight, 4.3 t; dia, 790 mm; length, 6.2 m; to be used in the 2nd stage of the *Scout* launch vehicle) and others. Attention is paid to the designing and utilization of solid-propellant engines 3.4 and 6.6 m in dia.

AMERICAN ROCKET SOCIETY (ARS). Founded in 1930. Developed a liquid-propellant engine in 1933 that lifted a rocket to an altitude of 76 m. In 1935 the ARS built a test stand and began experimenting with various types of rocket engines. Developed two types of regeneratively cooled engines in 1939—40. Tested a 4-nozzle rocket in 1944. The Society did no research work during World War II, but it continued to publish the magazine *Astronautics*. The ARS is a large professional organization engaged in research on guided missiles and space flight. Congresses, where rockets and rocket equipment are exhibited, are held annually.

AMINES. High-boiling fuels for liquid-propellant engines; derivatives of hydrocarbons containing the amino radical. Many aliphatic and aromatic amines and their mixtures have been used or tested as a starting (for initiating self-ignition) or basic fuel for liquid-propellant engines (e.g., *Tonka*-250, aniline, diethyl amine, and others).

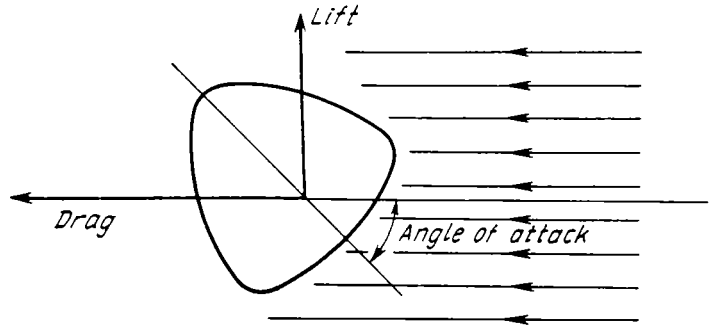
AMMONIA, liquefied, NH_3. A low-boiling colourless liquid fuel for liquid-propellant engines. It has a specific pungent odour; density, 0.682 g/cm^3 at —33.4°C; m.p., —77.7°C; b.p., —33.4°C. Poisonous, readily dissolves many substances, including certain metals; chemically stable, thermostable, a good cooling agent. Does not attack structural metals; however, copper is attacked only in the presence of oxygen. It is cheap, can be obtained synthetically in unlimited quantities from nitrogen and hydrogen and is one of the basic products of the chemical industry. Liquefied ammonia is used as a fuel for liquid-propellant engines in combination with LOX (USA) and other oxidizers.

AMPLFIYING AND CONVERTING DEVICES. See CONVERTING DEVICES.

ANDERS, William A. (born 1933, Hong Kong). US astronaut, USAF major. Received his B. Sc. at US Naval Academy in 1955 and M. Sc. at USAF Institute of Technology in 1962. Nuclear engineer at the Weapons Laboratory, Curtland Air Force Base. Joined the NASA group of astronauts in October, 1963. Anders was third pilot in *Apollo-8* spaceship flight he made with F. BORMAN and J. LOVELL. The *Apollo-8* was injected into a parking orbit round the Earth on December 21, 1968 and later started off towards Moon. After 10 orbits round the Moon, the spaceship returned to Earth on December 27.

ANGLE OF AERODYNAMIC TRIM of re-entry body. See AERODYNAMIC MOMENT.

ANGLE OF ATTACK. The angle between the longitudinal axis of an aircraft (or spacecraft) and the head stream of gas. The LIFT FORCE acting on the spacecraft or re-entry body is to a certain extent proportional to the angle of attack. Consequently, CONTROLLED RE-ENTRY can be accomplished by varying the angle of attack. The angle of attack can be changed by means of aerodynamic control surfaces or by varying the position of the spacecraft's



centre of mass in flight. The angle of attack can be changed only within definite limits because of a considerable rise in the kinetic temperature and the large aerodynamic loads encountered during the descent.

ANGULAR COORDINATES. 1. Angles determining the position of natural or artificial celestial bodies on the celestial sphere. 2. Angles determining the position of the spacecraft axes in space (see PITCH, YAW, ROLL). Spacecraft is frequently oriented in respect to the directions with which its axes should coincide. In this case, the angular coordinates are equivalent to the ERROR OF ORIENTATION.

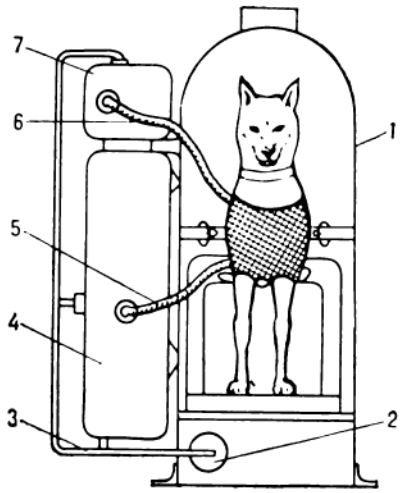
ANGULAR-RATE SENSOR. A spaceborne instrument determining the rate of spacecraft rotation. Angular-rate sensors are used in systems of angular stabilization and orientation of launch vehicles and other types of spacecraft. Gyroscopic angular-rate sensors (gyroscopic tachometers) having a high reliability, sensitivity and stability of operation are the most frequently used.

ANGULAR STABILIZATION. Control of angular movement of spacecraft at periods of considerable accelerations (e.g., during operation of the rocket engine or atmospheric braking of the re-entry body). Angular stabilization differs from ORIENTATION in that it serves as an auxiliary means of controlling the motion of the spacecraft centre of mass and, in particular, of keeping the rocket engine thrust or lift force in a definite direction. Systems of angular stabilization must oppose the effect of relatively large disturbing torques, and, therefore, employ more powerful engines than those used for purposes of orientation.

ANILINE, $C_6H_5NH_2$. An oily, yellowish high-boiling liquid, density 1.022 g/cm^3 at 20°C; m.p., —6.2°C; b.p., 184.4°C. Poisonous, chemically stable. Does not attack structural materials. Used in Germany, USA and

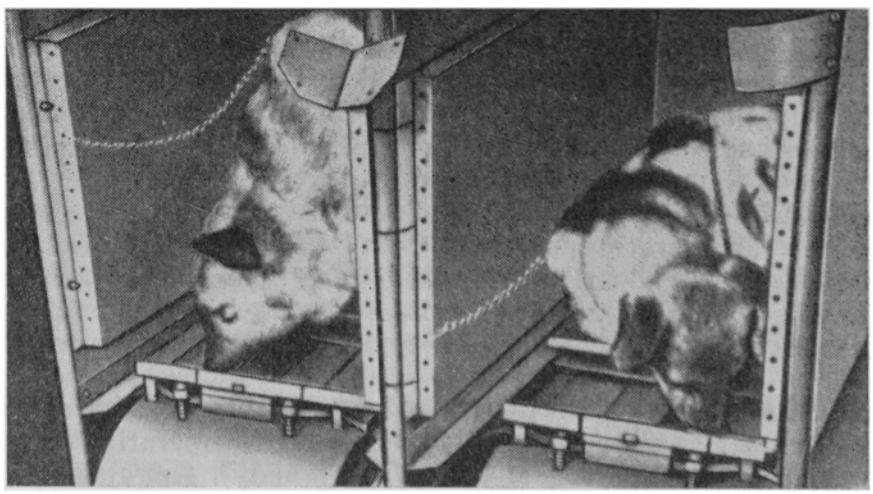
France as a rocket fuel or a fuel component in combination with NITRIC ACID and NITRIC ACID ROCKET OXIDIZERS; it ignites spontaneously with these oxidizers. Furfuryl alcohol (20% by weight) or other substances are added to aniline to lower its m.p.

ANIMAL FEEDING in spaceship. Two methods have been tested. The first consists in automatic feeding by means of a periodically moving conveyor with recesses containing boxes with a gelatinous mixture of highly calorific food and water. Each box moves into alignment with a hatch before the animal's front paws. When the hatch opens with the characteristic noise the animal has been trained to, it begins eating. The second method consists in transporting food and water by air pressure from containers via a food supply tube directly into the animal's stomach.



Dog feeding in *Cosmos-110* satellite

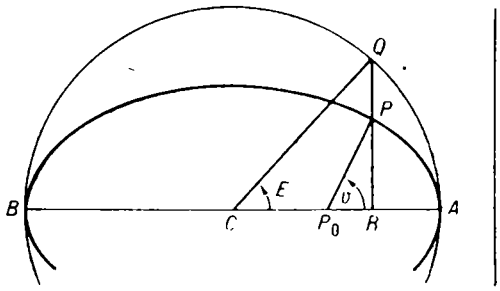
1—sealed container with animal; *2*—pneumatic system with compressed air bottle; *3*—tube; *4*—food container; *5*—food supply tube; *6*—hose; *7*—pharmacological container.



Automatic device for dog feeding in second Soviet Earth satellite *Sputnik-2* and second Soviet spaceship.

ANNIHILATION ROCKET ENGINE. A hypothetical photon engine in which energy is emitted as a result of annihilation of matter, i.e., interaction of particles and anti-particles causing their complete transformation into photons.

ANOMALY, ECCENTRIC. An auxiliary variable of ELLIPTIC MOTION, dependent on time in KEPLER'S EQUATION. Eccentric anomaly is measured from the PERICENTRE in the direction of the motion of the celestial body and can vary from 0 to ∞. The geometrical meaning of eccentric anomaly is as follows: let APB (see Fig.) be an elliptical orbit, and A, P_0 and C — the pericentre, focus and centre of orbit, respectively. Let AQB be a circle with the centre in C and radius equal to the SEMI-MAJOR AXIS. Then if P is the position of the celestial body at the moment t and PQ is perpendicular to the major axis of the ellipse, the eccentric anomaly is equal to the angle ACQ.



ANOMALY, MEAN. The angle between the radius-vector of a celestial body and the direction to the PERICENTRE of the orbit, on the assumption that the body moves at a uniform angular velocity. Mean anomaly is measured from the pericentre of the orbit in the direction of motion of the celestial body and can vary from 0 to ∞.

ANOMALY OF GRAVITY. The difference between the observed value of gravity at a point of the Earth and its theoretical (normal) value for the same point calculated on certain assumptions about the Earth's inner structure. Thus, the anomaly of gravity depends on the accepted expression for the normal force of gravity.

ANOMALY, TRUE. The angle between the radius-vector of the celestial body and the direction to the PERICENTRE of the orbit. True anomaly is measured from the pericentre in the direction of the motion of the celestial body and can vary from 0 to ∞.

ANTENNA. A device used for radiating (transmitting) or intercepting (receiving) electromagnetic waves. Antennas are classified as directional, designed to radiate or receive radio waves in some directions better than others (see DIRECTIVITY PATTERN), and omnidirectional, radiating and receiving radio waves equally well in all directions. Antennas are also characterized by their power gain (gain in power due to the directional effect of the antenna) and the ANTENNA EFFECTIVE AREA.

ANTENNA EFFECTIVE AREA. A certain area expressed in m^2 from which the antenna, directed towards the source of the signal received, "gathers" the energy of the electromagnetic oscillations. In the case of parabolic and horn-parabolic antennas, the antenna area amounts to 0.35—0.55 of the geometric area of the antenna aperture.

ANTIMATTER. Matter constituted of antiparticles (antiprotons, antineutrons, positrons). A hypothesis exists that certain cosmic objects, such as comets, are composed of antimatter. Any contact between a spacecraft and a piece of antimatter would cause an explosion.

ANTIPODE EFFECT. See IONOSPHERIC REFLECTION OF RADIO WAVES.

APEX of solar motion. A point on the celestial sphere towards which the Sun moves (in the Hercules constellation); the opposite point is the antiapex.

APHELION. The point in the orbit of a satellite of the Sun (as a planet, spacecraft, etc.) at the greatest distance from the centre of the Sun.

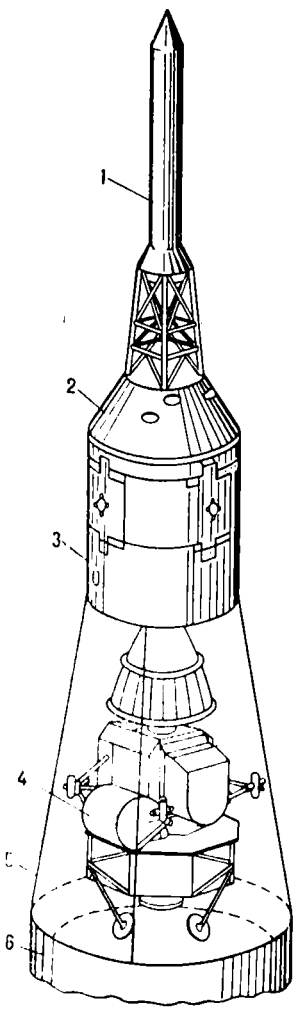
APHELION DISTANCE. The distance of the APHELION from the centre of the Sun.

APOCENTRE. The point of an orbit farthest from the centre of attraction. For planets of the solar system the apocentre is called the APHELION. In case of Earth satellites, including the Moon, it is called APOGEE.

APOGEE. The point in the orbit of a satellite of the Earth (as the Moon or artificial Earth satellite) at the greatest distance from the centre of the Earth.

APOGEE DISTANCE. The distance of the APOGEE from the centre of the Earth.

APOLLO. Name of US spaceships for manned flight to the Moon and their development and flight programme. The *Apollo* is launched by a *Saturn-5* vehicle which made its first flights in late 1967 and early 1968. *Apollo* consists of 2 modules linked for flight towards the Moon and in circumlunar orbit. One, the *Command and Service Module* (*CSM*), accommodates 3 spacemen, and the other, the *Lunar Excursion Module* (*LEM*), is used by 2 of the spacemen for landing on the Moon and subsequent take-off into Moon satellite orbit. Then the *LEM* docks with the *CSM*, in which the entire crew returns to Earth. Complete with engines and propellant, *Apollo* weighs ~43 t. The duration of the first mission of *LEM* on the lunar surface will not exceed 1 day. The *CSM* of *Apollo* comprises a re-entry body, which accommodates the crew throughout the flight, and a propulsion compartment. The re-entry body is a cone 3.84 m in dia and 3.4 m high; it weighs 5.6 t. The propulsion compartment weighs 22.8 t (17.6 t propellant included), its liquid-propellant engine with a thrust of 10 t is pressure-fed a propellant consisting of nitrogen tetroxide and Aerosene-50. Propellant included, *LEM* weighs ~14.5 t, its height is 7 m. *LEM* consists of 2 stages: a descent stage with landing gear and take-off stage incorporating a sealed cabin for spacemen. The liquid-propellant engine of the descent stage has a controlled thrust of 0.47—4.76 t, that of the take-off stage, a thrust of 1.6 t. Both engines are pressure-fed



Schematic representation of *Apollo* spaceship mounted on *Saturn* launch vehicle.

1—rocket engine of emergency escape system; *2*—re-entry capsule of orbital spaceship (*Command and Service Module*); *3*—engine compartment of orbital spaceship; *4*—*Lunar Excursion Module* (Moon landing cabin); *5*—adapter for mating *Apollo* spaceship to launch vehicle; *6*—last stage of launch vehicle.

and burn nitrogen tetroxide and Aerosene-50. After injection into a moonward trajectory, the modules of the spaceship change places: *CSM* is turned 180° and joined with the *LEM* so that the spacemen can pass into the latter.

Apparent acceleration

The *Apollo* has been flown since 1967. On November 9, 1967, *Apollo-4* (unmanned) was injected by a *Saturn-5* into a geocentric orbit to test re-entry at a velocity of 11 km/s attained by rocket acceleration. *Saturn-1B* launched *Apollo-5* (unmanned) on January 22, 1968, to verify the *LEM* and its rocket engine in circumterrestrial orbit. On April 4, 1968, a *Saturn-5* launched *Apollo-6* (unmanned) into orbit round the Earth. A number of failures during the flight cut short its programme. The *Apollo-7 CSM*, manned by W. Schirra, D. Eisele and W. Cunningham, was launched by a *Saturn-1B* on October 11, 1968; it splashed down in the Pacific after orbiting the Earth 163 times in 10.7 days. *Apollo-8* whose *CSM* accommodated astronauts F. Borman, D. Lovell and W. Anders, was launched towards the Moon by a *Saturn-5* on December 21, 1968; on December 24 it went into selenocentric orbit (perilune 112 km, apolune 312 km; after correction, the orbit became circular at an altitude of 113 km) and made 10 revolutions round the Moon; it splashed down in the Pacific on December 27, 1968. The flight programme included scientific investigations, TV reporting, photographic and visual observations of the lunar surface to evaluate the pre-selected landing sites. *Apollo-9* with the astronauts J. McDivitt, D. Scott and R. Schweickart on board was launched by a *Saturn-5* on March 3, 1969, and performed a 10-day flight aimed to proof-test the *LEM*. *Apollo-10* carrying astronauts T. Stafford, J. Young and E. Cernan was launched May 18, 1969, by *Saturn-5* and on May 21 it became the second manned spaceship to go into selenocentric orbit. Its mission was to debug the manoeuvring system in circumlunar space. The orbit perilune was 110 km and apolune 313 km, which were corrected to 111 and 113 km, respectively. T. Stafford and E. Cernan transferred to the *LEM*, separated it from the *CSM* and descended to an altitude of 15 km from the surface of the Moon. The orbit was then changed; its perilune became 23 km, apolune, 380 km. The *LEM* flight lasted for ~8 h; then it disengaged the descent stage, approached the *CSM* and docked. When the astronauts transferred to *CSM*, the *LEM* was jettisoned. On May 24, in the 32nd circumlunar orbit, the propulsion system was fired to inject the spaceship into trans-Earth trajectory. The spaceship spent a total of 61 h 40 min in selenocentric orbit. The 8-day flight terminated in a splash-down in the Pacific. During the flight, scientific investigations, observations, and photographs were made, and TV reports transmitted.

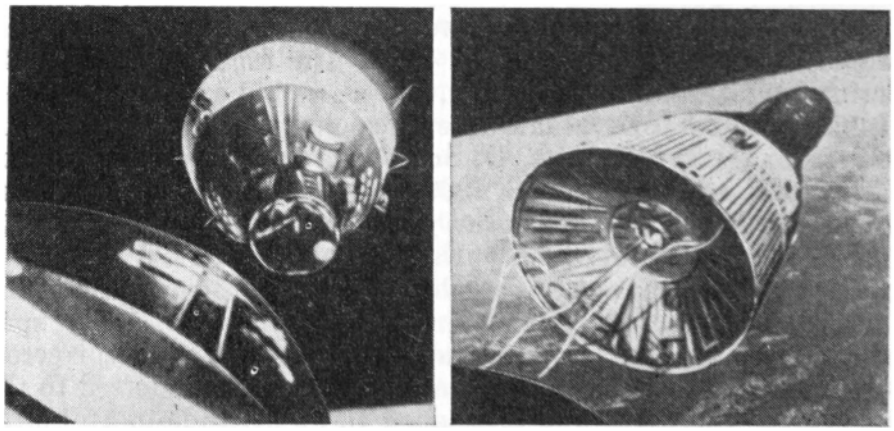
APOLUNE. The point in the orbit of an artificial Moon satellite at the greatest distance from the centre of the Moon.

APPARENT ACCELERATION. The total acceleration imparted to the spacecraft by all acting forces (engine thrust, atmosphere drag, etc.) with the exception of gravitational forces. The apparent acceleration differs from the actual one by the acceleration that is imparted to the spacecraft by the attraction of the Sun and planets; when flying within a strong gravitational field (e.g., in the vicinity of the Earth), the difference between the actual and apparent acceleration may be considerable.

APPARENT VELOCITY. The velocity determined according to the APPARENT ACCELERATION of the spacecraft. The apparent velocity may differ considerably from the actual one in case of travel in a gravitational field. The apparent velocity is determined by LINEAR ACCELERATION INTEGRATORS or computers that process the readings of ACCELEROMETERS.

APPARENT VELOCITY REGULATOR. An assembly of devices used for measuring the APPARENT VELOCITY of the spacecraft and checking its conformity with the pre-determined (calculated) value. The apparent velocity regulator increases or reduces the thrust of the rocket engines according to the deviation of the apparent velocity from its pre-computed value. Apparent velocity regulators are used in the control systems of continuously operating high-thrust rocket engines, e.g., those of launch vehicles or other spacecraft performing vigorous MANOEUVRES.

APPROACH. A series of successive manoeuvres to bring spacecraft close to each other. Performed for different purposes (see INSPECTION, DOCKING, IN-ORBIT ASSEMBLY), the main types being INTERCEPTION and SOFT APPROACH.

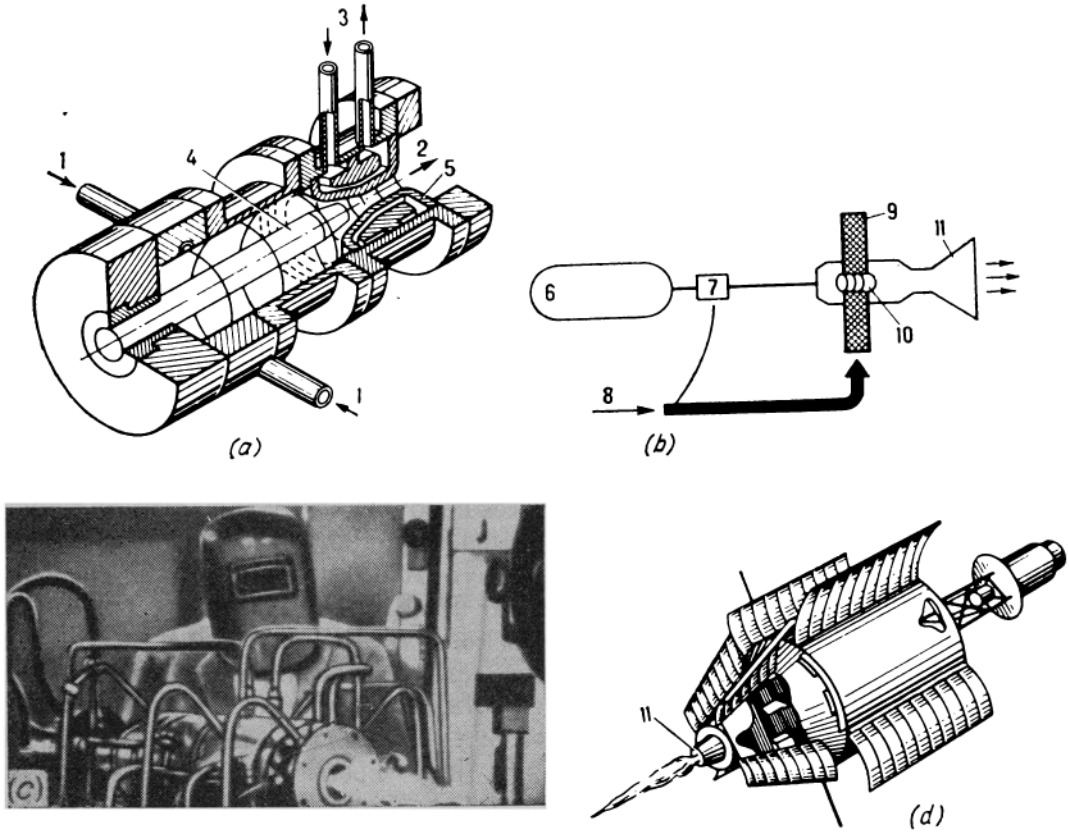


Orbital approach of *Gemini-6* and *Gemini-7* spacecraft.

ARC ROCKET ENGINE. An electrothermal rocket engine wherein the working fluid is heated by a stabilized electric arc. Usually serving as the working fluid in the arc rocket engine are light substances with a low molecular weight, e.g., hydrogen or helium. The exhaust velocity of the working fluid reaches 20 km/sec. This engine is in the experimental stage. See Fig., p. 39.

ARGUMENT OF LATITUDE. The angle between the radius vector of a celestial body and the LINE OF NODES. The argument of latitude is measured from the ascending node (see ORBITAL ELEMENTS) in the direction of the motion of the celestial body and can vary from 0 to ∞.

ARMSTRONG, Neil A. (born 1930, Wapakoneta, Ohio). American astronaut. Graduated (1955) from Purdue University, Lafayette, Ind., as B.Sc. in aeronautical engineering. Served in the US Navy, later with the Lewis Flight Propulsion Laboratory as a test pilot. Tested jet planes, including

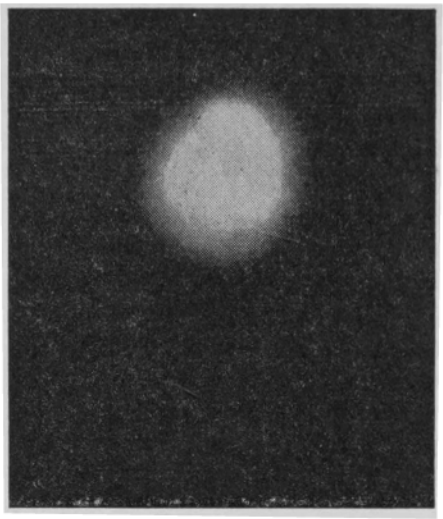


Arc rocket engine: (*a*) and (*b*) diagrams; (*c*) *Avco* (USA) "plasmatron" for generation in laboratory of jets at temperature of 10,000°C; (*d*) spacecraft propelled by arc rocket engine with hydrogen as working body and atomic reactor as electricity generator.

1—working fluid supply; *2*—reaction jet (efflux); *3*—coolant; *4*—electrode; *5*—nozzle-electrode; *6*—working fluid; *7*—pump; *8*—current lead; *9*—electrodes; *10*—electric arc; *11*—thrust chamber.

the *X-15* experimental rocket plane. In 1962 joined the NASA group of astronauts. Made an orbital flight (together with D. Scott) on March 16, 1966, in a two-seat *Gemini-8* spacecraft which he was in command of; it circled the Earth 7 times in 10 h 40 min. In the course of this flight, orbital docking with an *Agena* target rocket was achieved for the first time. Unforeseen oscillations of the rocket and spacecraft began 20 min after docking; *Gemini-8* separated from the rocket and landed ahead of schedule.

"ARTIFICIAL COMET". The name given to a cloud of sodium vapours ejected from a space rocket at a definite point of its trajectory. It is a means for visual observation of rocket flight and determination of its trajectory, as well as for scientific experiments. The sodium vapours forming the cloud of an artificial comet are in the atomic condition and intensely disperse sunrays of a definite wave-length. This permits the cloud to be observed with light filters even against the background of a relatively bright sky. Such artificial comets were formed during the flights of the Soviet automatic interplanetary stations Luna-*1* and *Luna-2*. At a distance of 113—150 thou. km their brightness was equivalent to that of stars of the 4th to 6th magnitudes. To

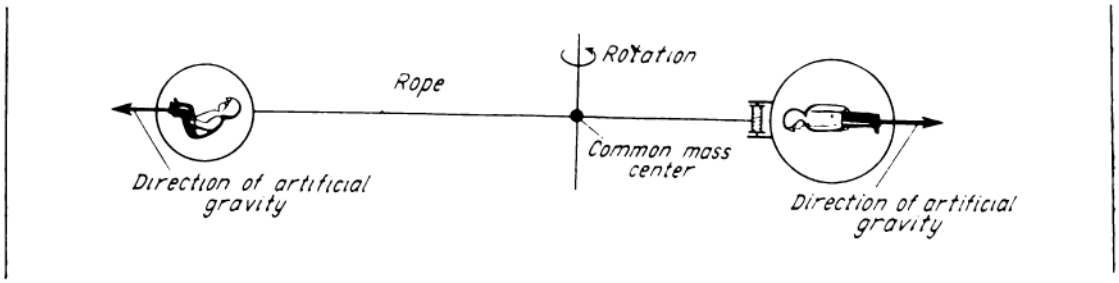


Photograph of artificial comet obtained at 03.56'20" a. m., Moscow Time, January 3, 1959 (*Luna-1*)

produce the artificial comet, the last stage of the launch vehicle had a vapourizer capable of ejecting 1 kg of sodium in 5 to 7 s. See Fig.

ARTIFICIAL EARTH SATELLITE. A spacecraft intended for flight on a geocentric orbit. For injection into such an orbit, a velocity equal to or greater than FIRST COSMIC VELOCITY must be imparted to the vehicle. Artificial Earth satellites must fly at heights no less than 150—160 km in order to avoid rapid deceleration in the Earth's atmosphere while the maximum height of flight (apogee of the orbit) may reach several hundred thousand km. The motion of artificial Earth satellites is governed by the laws of celestial mechanics. The period of a satellite (time of one revolution) depends upon the mean altitude of flight and may range from 90 min to several days. The satellites serve various scientific and practical purposes (see SCIENTIFIC SATELLITE, COMMUNICATIONS SATELLITE, METEOROLOGICAL SATELLITE, NAVIGATION SATELLITE, MILITARY EARTH SATELLITE). By January 1, 1969, some 850 satellites of different types had been launched (see SOVIET EARTH SATELLITES).

ARTIFICIAL GRAVITY. A means of providing comfort and habitation conditions approximating those on Earth for a spaceship crew on a prolonged flight. It also facilitates starting of the space-borne liquid-propellant engines. Short-time artificial gravity can be developed by starting rocket engines to accelerate the centre of mass of the spaceship; this method is used to assure



starting of powerful liquid-propellant engines (prior to firing the main engine, small auxiliary engines are run for a certain period of time). To develop artificial gravity for long periods of time, the spaceship is spun about one of its axes. The centrifugal forces in the modules far from the axis of rotation replace the natural gravity. One way of developing artificial gravity on two spaceships is to interconnect them with a wire rope and cause them to spin about their common centre of mass. In this case the magnitude of the artificial weight is easily regulated by altering the length of the rope.

ARTIFICIAL LUNAR SATELLITE. A spacecraft for selenocentric orbital flight. The satellite must have a rocket engine to decelerate it on entry into the ACTIVITY SPHERE OF MOON, since the Moon's gravity is too weak to capture a spacecraft sent from the Earth. The world's first artificial lunar satellite was the Soviet automatic interplanetary station *Luna-10* launched on March 31, 1966. Other lunar satellites include *Luna-11*, *-12* and *-14*, *Lunar Orbiters-1* through *-5*, and *Explorer-35*. Lunar satellites are used to investigate circumlunar space, take measurements of the Moon's gravitational field and other physical characteristics, and to study its relief by photography and TV observation. *Luna-12* and *Lunar Orbiters* relayed photos of the lunar surface to Earth via TV channels. *Luna-10* γ-radiation measurements made it possible to determine the composition of lunar rock. Study of the *Luna* and *Lunar Orbiter* orbits provided more accurate data on the Moon's gravity. By January 1, 1969, ten unmanned lunar satellites have been launched into a variety of orbits with perilunes ranging from 40 to ~800 km, apolunes from 870 to ~6400 km, and inclinations from 11° to 85.5°. On December 24, 1968, the *Apollo-8* went into selenocentric orbit (minimum altitude ~110 km) to make 10 revolutions in it and return to the Earth. On May 21, 1961, *Apollo-10* went into selenocentric orbit (perilune 110 km; apolune 313 km; after correction 111 and 113 km, respectively). The *Lunar Excursion Module* carrying two astronauts was separated from the spaceship and descended to 15 km above the surface of the Moon; it then went into an orbit with a perilune of 23 km and an apolune of 380 km, and later docked with the spaceship. On May 24, after 61 h 40 min in orbit, during the 32nd revolution round the Moon, the spaceship changed to trans-Earth trajectory.

ARTIFICIAL PLANET. A spacecraft launched into a heliocentric orbit, i.e., outside the gravitational field of the Earth or other planets, to become an artificial satellite of the Sun. Injection into this orbit requires a speed no smaller than SECOND COSMIC VELOCITY. *Luna-1* launched in January, 1959, by the Soviet Union was the first man-made planet. The Soviet and American spacecraft which have become artificial planets include *Luna-1*, *-4*, and *-6*; *Venyera-1* and *-2*; *Mars-1*; *Zond-1*, *-2* and *-3*; *Pioneer-3* and *-5*; *Ranger-3* and *-5*; *Mariner-2*, *-3* and *-4*; *Surveyor* (*Mk. 1*). They travel between the orbits of Venus and Mars, their least distance from the Sun being 97,000,000 km (*Zond-1*) and greatest ~214,000,000 km (*Mariner-4*).

ASSEMBLY JIG. A structure in the vehicle assembly building for horizontal assembly of launch vehicles.

ASTEROIDS. See MINOR PLANETS.

ASTROBIOLOGY. See EXOBIOLOGY.

ASTROBOTANY. A branch of EXOBIOLOGY dealing with the problems of possible vegetation on planets, particularly with the effect of the environment on optical (mainly spectral) properties of vegetation, etc. Astrobotany was founded by G. A. Tikhov, a Soviet astronomer. It considers, among other things, that the hypothesis of life on Mars is compatible with the absence of increased reflectivity of the dark regions of Mars in IR light (the Wood effect). Experiments with Earth's vegetation in cold climates have shown that the Wood effect disappears, this being a defence reaction to low temperature. Tikhov and his followers have carried out important

research into the temperature dependence of the appearance of the absorption band of chlorophyll, into variations in the colour of the Earth's vegetation in the seasons and latitudes, etc. Astrobotany holds that there is a basic resemblance between life on Earth and life on other planets, particularly Mars.

ASTROCORRECTION of the gyrostabilized platform of a spacecraft. Correction of the platform's angular position according to signals obtained from STAR SENSORS that determine the direction towards a star or some other celestial reference point. Astrocorrection is used when the angular position of the platform deviates considerably from the pre-set course due to drift during a long term of service.

ASTRO-INERTIAL NAVIGATION. A method of space navigation combining INERTIAL NAVIGATION and ASTRONAVIGATION. It is employed mainly for ASTROCORRECTION of gyrostabilized platforms.

ASTROMETRY. The branch of astronomy dealing with determination of positions of celestial bodies, their dimensions and motions. The purposes of astrometry are: (a) to develop procedures (including systems of coordinates for celestial bodies) and to design high precision astronomical measuring instruments; (b) to compile stellar catalogues based on observations; (c) to make measurements to solve problems in astronomy such as investigation of the irregularity of Earth's rotation, the movement of the poles on its surface, etc. The solution of astronomical, geodetic, geophysical and other problems is based on observations made with the help of a theodolite, engineering and astronomical transits, and other instruments that are constantly being improved to eliminate the influence of measurement error and the outer environment. This work is based on the results of investigations in SPHERICAL ASTRONOMY, CELESTIAL MECHANICS, and other branches of astronomy. The first two stellar catalogues containing over 800 and 1000 stars were compiled in IV century BC. In the 19th and 20th centuries a number of catalogues describing the positions of tens of thousands of stars and containing sky observations of the approximate coordinates of hundreds of thousands of stars, to the 10th STELLAR MAGNITUDE, have been compiled. During the past 30 years all Soviet and many foreign observatories have collaborated in the compilation of a new *Catalogue of faint stars*, which is nearing completion. It will list approximately 26,000 stars of 7.5 to 8.5 stellar magnitudes. Also, a new and more advanced system of coordinates of celestial bodies is being developed.

ASTRONAUT. The term used in a number of countries instead of COSMONAUT.

ASTRONAUTICAL CONFERENCES. International and national scientific meetings concerned with problems of space science and exploration. Among the most important international conferences are those held by the INTERNATIONAL ASTRONAUTICAL FEDERATION yearly since 1950, usually in the autumn, in different member countries of the IAF. For example, the 15th congress was held in Warsaw in 1964, the 16th congress, in Athens in 1965, and the 17th congress, in Madrid in 1966. The general sessions of IAF congresses are ordinarily devoted to the following problems: rocket engines, astrodynamics, space navigation, guidance and tracking of space vehicles, re-entry, design of space systems, meteorological, communications and geodetic satellites, bioastronautics and life-support systems. During IAF

congresses, symposia of the INTERNATIONAL ACADEMY OF ASTRONAUTICS and colloquia of the International Institute of Space Law are held. Plenary meetings of COSPAR are also held annually, with simultaneous international scientific symposia where all scientists may present papers on the results of research done with the aid of Earth satellites, space probes, rockets or balloons. Conferences are likewise convened by international scientific associations and organizations (International Union of Pure and Applied Physics, International Union of Geodesy and Geophysics, International Scientific Radio Union, International Telecommunications Union, International Federation of Automatic Control, etc.) and by national organizations (NASA, American Geophysical Union, American Institute of Aeronautics, German Society of Orientation and Navigation, etc.). Congresses, conferences, and meetings on space flight are held in all countries concerned.

ASTRONAUTICS. The term used in a number of countries, specifically in the USA, to denote space science and exploration instead of the term COSMONAUTICS, accepted in the USSR. Astronautics means "flight to the stars", while cosmonautics, which means "flight through space", is a comprehensive term that more precisely defines mankind's present tasks in the exploration of outer space.

ASTRONAVIGATION. A method of directing spacecraft by measuring the angles between lines joining the spacecraft and definite reference bodies of the solar system (the Sun, planets, planet satellites), or, alternatively, the angles formed when these lines are aimed at known fixed stars; this makes it possible to determine the position of a spacecraft in the solar system. STAR SENSORS, SOLAR SENSORS and VERTICAL-LINE PLOTTERS can serve as astronavigational sensing elements. Another method of astronavigation determines the position of the spacecraft by measuring the moment at which heavenly bodies rise above the edge of the planet approached in the course of the flight.

ASTRONOMICAL COUNCIL OF THE ACADEMY OF SCIENCES OF THE USSR. An organization for planning and coordinating astronomical research in the USSR. It is also the national committee of Soviet astronomers and represents the USSR in the International Astronomical Union and other international organizations. The Astronomical Council was established in 1937. It embraces prominent researchers in astronomy and allied sciences. The Astronomical Council functions through 15 commissions that coordinate their research work in various branches of astronomy. It also directs optical observation of artificial Earth satellites in the USSR.

ASTRONOMICAL UNIT of length. (1) Astronomical unit of length (AU) is the mean distance between the Earth and the Sun equal to $14.95 \times \times 10^7$ km. (2) Parsec is the distance at which the annual parallax of a star is an angle of 1″ of arc; 1 parsec = 206,265 AU = 3.26 light years = $30.8 \times \times 10^{12}$ km. (3) Light year is the distance travelled by light in a year; 1 light year = 9.4×10^{12} km.

ASTRONOMY. The science dealing with the Universe and the bodies of the SOLAR SYSTEM, stars, nebulae, galaxies and extragalactic nebulae forming the Universe. Astronomy is the study of motions, forms, dimensions, masses, nature, structure, physical conditions, chemical composition, origin and evolution of celestial bodies as well as INTERPLANETARY MEDIUM

and INTERSTELLAR MEDIUM. Astronomy is closely allied with mathematics, physics, chemistry and other sciences. Astronomical techniques include spectroscopy, photometry, photography and other optical and radio-technical methods. Since 1957, use has been made of electronic and other instruments carried on board artificial Earth satellites, artificial lunar satellites and automatic interplanetary stations sent to Mars, Venus and the Moon, or landed on the lunar surface. According to the method used and the objects of research, astronomy is divided into the following branches: ASTROMETRY, SPHERICAL ASTRONOMY, CELESTIAL MECHANICS, STELLAR ASTRONOMY, COSMOGONY, COSMOLOGY, EXTRAGALACTIC ASTRONOMY, ASTROPHYSICS, RADIO ASTRONOMY, and GRAVIMETRY.

ASTRO-ORIENTATION. Orientation of spacecraft with reference to fixed stars by the use of STAR SENSORS. Employed in astrophysical research work, accurate manoeuvring of spacecraft and other cases when the permissible ERROR OF ORIENTATION is small and equals a few angular minutes or seconds.

ASTROPHYSICS. The branch of astronomy dealing with the physical nature of celestial bodies and processes in their atmospheres. Astrophysics is subdivided into physics of the Sun, the Moon, planets, stars, nebulae, comets and meteors. Astrophysical research is based on analysis of spectra of celestial bodies, e.g., their chemical composition is judged by the emission or absorption lines, line intensities are indicators of temperatures in solar and stellar atmospheres, the position and shift of spectral lines denote radial velocities, from the character of emission and absorption lines conclusions can be drawn as to the processes in stellar atmospheres (velocity of turbulent motion, atmospheric densities), the rate of stellar rotation, solar and stellar magnetic fields, etc. Photometric and polarimetric studies of planets and their satellites reveal the nature of their surfaces, etc. Technical facilities of astrophysics include TELESCOPES equipped with spectrographs, photometers, cameras, electronic and TV devices, etc. Only in very limited regions of the entire spectrum of electromagnetic radiation the Earth's atmosphere is transparent. These regions are: the optical window (from 3000 Å to 3 μ), the IR window (from 8 to 14 μ) and the radio window (from a few mm to 40 m). Radiation of all wavelengths shorter than 3000 Å is absorbed by atmospheric gases (ozone, oxygen and nitrogen) that protect vegetation and animal life on Earth from destructive short-wave solar radiation. Radiation in the region between the optical and radio windows is absorbed by water vapour in the lower layers of the Earth's atmosphere. Beyond the radio window, the terrestrial ionosphere absorbs or reflects all radiation.

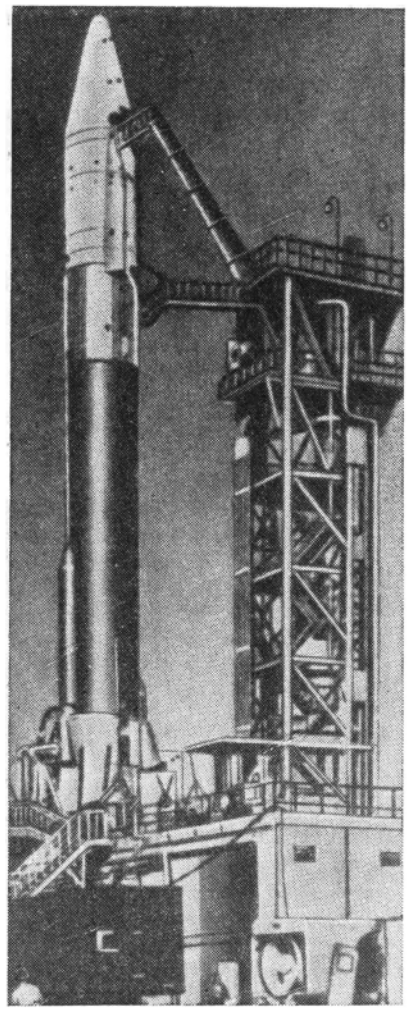
The main technique of astrophysics is the study of the electromagnetic radiation of celestial bodies by means of optical and radio methods and instruments (see RADIO ASTRONOMY). Measurements of thermal radiation in the IR window with sensitive detectors permit estimation of surface temperatures of the Moon and planets (a detailed thermal chart of the Moon already exists), registration of the so-called cold stars, etc. In order to minimize the adverse effect of the Earth's atmosphere on astronomical observations, telescopes have been set up at high altitudes, in mountain areas. In the '60s, the balloon-borne telescopes ascended to altitudes of 20 km and over. The range of investigations has thus been extended, and it has become

possible at an altitude of 40 km to detect water vapour in the atmospheres of Mars and Venus. This branch of astrophysics was called balloon astronomy. In the '40s short-wave spectra of the Sun were obtained when rocket-borne instruments were taken up beyond the Earth's atmosphere (rocket astronomy). The launching of the first Earth satellite initiated a new branch, the satellite or cosmic astronomy. Celestial bodies are systematically observed from Earth satellites and spacecraft flying past the Moon, Mars, Venus and in interplanetary space. As early as *Sputnik-II* satellites began to carry instruments for studying solar radiation in the short-wave region of the spectrum. Later, the solar spectrum was studied not only in the UV, but also in X-rays. Sensitive detectors have also registered X-rays emitted by galactic and extragalactic sources. Instruments carried by the *Luna-12* lunar satellite detected X-ray emission from the Moon's surface as a secondary effect of fluorescence under solar X-ray emission. (This was the birth of X-ray astronomy.) The study of γ-ray emission from lunar matter registered by instruments on board *Luna-12* made it possible to determine the nature of rocks on the surface of the Moon. There is evidence that the Sun emits γ-rays during its active period and as a result, a new branch of astrophysics called gamma astronomy is now developing.

The progress in space flight has confronted astrophysics with many new problems such as: (a) investigation of soil strength for landing of spacecraft on the Moon; (b) study of Martian atmospheric density in order to decide on the mode of decelerating spacecraft approaching its surface; (c) measurements of Venus's atmospheric temperature; (d) research into the nature of solar flares (which present a radiation hazard for spacemen), and the forecast of such flares for manned space flights.

ASYNCHRONOUS CULTURE. A complex-age population (totality of a single species) of unicellular algae, among which individual cells are in different stages of growth. Asynchronous cultures are an important element of the self-contained LSS of a spaceship and are characterized by stability of production in time.

ATLAS. Name of a series of American launch vehicles using the *Atlas* intercontinental ballistic missiles as first two stages. These launch vehicles have a take-off weight of 125—135 t and total height of 31—36 m. The first stage is a cluster of 3 liquid-propellant engines firing LOX and kerosene, its total



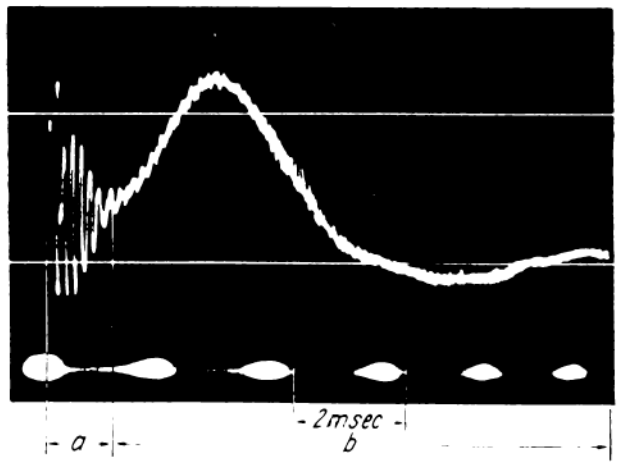
American launch vehicle *Atlas-Centaur*.

thrust is 163 t. In the *Atlas-Agena* combination, the 3rd stage is an *Agena-D* rocket, while in the *Atlas-Centaur* combination it is a *Centaur* rocket (see Fig.). Depending on the combination used, the payload placed in orbit ranges from 2.2 to 4.5 t. The *Atlas* vehicle has been used in launching the *Midas*, *Samos*, and USAF satellites, the *Ranger* and *Mariner* automatic interplanetary stations, etc.

ATMOSPHERIC MOISTURE CONDENSATE. A liquid obtained in spacecraft sealed cabins as a result of condensation of water vapours excreted by living organisms. It contains insignificant quantities of volatile substances excreted by man's skin and exhaled from the lungs, the chemical substances yielded by structural materials and equipment of the spaceship, as well as volatile substances from sanitary waters, food products and their remnants. The daily volume of condensate from one man is 1—2 l. Consequently, this can be a source for replenishment of the water supply during flights lasting over 2 weeks. The water regenerated from the condensate is sufficient to meet one half the daily requirements of a man, which is 4 l, including the minimum quantity of water necessary for sanitary and hygienic purposes (1.8 l), food preparation (1 l) and drinking (1.2 l). Various physico-chemical methods, including FREEZE DRYING, can be used for WATER REGENERATION from condensate. The regeneration of water from condensate containing considerable quantities of admixtures requires additional purification, irradiation or photochemical oxidation.

ATMOSPHERIC NOISES. Irregularly varying currents arising in radio receiver input circuits due to the absorption and re-emission of solar energy by the Earth's atmosphere. This noise increases during heavy rainfall; it is relatively low when the radio receiver is situated at great heights above sea level. Atmospheric noises appear at wavelengths of less than 5 cm and are particularly intense at wavelengths of 1.5 and 0.5 cm. Wavelengths of over 5 cm are mainly utilized in space communication to reduce the noise level.

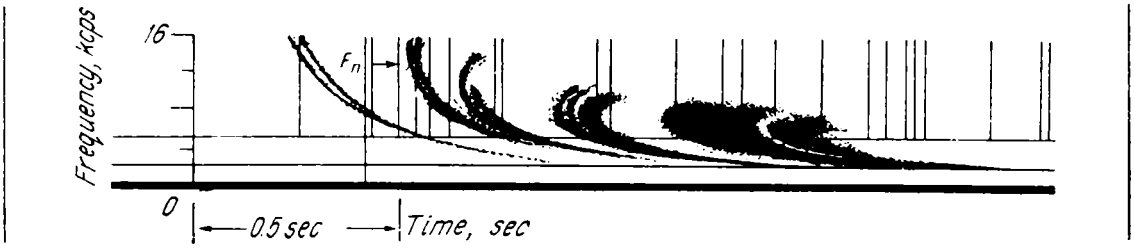
ATMOSPHERICS. Electromagnetic signals propagated in the Earth-IONOSPHERE wave guide. Their source is lightning discharge. In a number



Oscillogram of atmospherics: (*a*) high-frequency component part; (*b*) tail of the atmospherics.

of instances, atmospherics escape from the wave guide and propagate in the outer ionosphere along the lines of force of the magnetic field producing ATMOSPHERIC WHISTLERS. Atmospherics consist of two components: an HF component $f \simeq 1000$—$50{,}000$ c/s, and a low-frequency component, or tail, $f \simeq 10$—1000 c/s. The HF component in most cases (70%) is a quasi-periodic oscillation of an increasing period, its duration being 600—1000 μsec. The tails last from 6—8 to several dozen μsec, they consist of 2 or 3 half-periods and are observed in approx. 30% of the atmospherics. The spectrum of atmospherics has two maxima in the vicinity of frequencies $f \simeq 70$—150 c/s and $f \simeq 6000$—$10{,}000$ c/s, respectively. Atmospherics are widely used for investigating the propagation of low-frequency and super-low frequency radio waves near the Earth. Recording of atmospherics on fixed frequencies provides information on the intensity of atmospheric radio interference.

ATMOSPHERIC WHISTLERS. Electromagnetic signals, i.e., atmospherics, that have passed through the dense layers of the ionosphere and travel back and forth (once or several times) mainly through the outer ionosphere along



the lines of force of the geomagnetic field between magnetically-conjugated (mirror) points. Due to considerable dispersion of velocities of electromagnetic waves in the ionosphere, the atmospheric dissipates, its duration becomes equal to 1—3 s or more; first to arrive are waves of the so-called nose frequency, followed by waves of higher and lower frequencies (see Fig.). The characteristics of the spectrum of atmospheric whistlers are determined by the intensity of the magnetic field and the concentrations of electrons and ions along the trajectory; the spectrum embraces frequencies from several hundreds to 20,000—30,000 c/s. Atmospheric whistlers are observed at the Earth's surface and in the ionosphere, by satellites and rockets. The number of signals and their intensity increase in the ionosphere. Analysis of the properties of atmospheric whistlers permits to determine electron concentration up to an altitude of 20,000—30,000 km; through it a sharp turn (a knee) in the electron distribution at altitudes of 12,000—22,000 km, as well as distortion of the structure of the magnetic field in the outer ionosphere during magnetic storms have been discovered. Satellites have registered low-frequency branches of the spectrum (ionic atmospheric whistlers) at frequencies less than 400—500 c/s, from which relative ion and electron concentrations as well as other parameters of the ionosphere are determined.

ATOMIC ROCKET ENGINE. An erroneous term for NUCLEAR ROCKET ENGINE.

ATOMIZATION OF LIQUID PROPELLANT. The dissipation of a liquid jet from a rocket engine's INJECTOR into drops, and their break-up into still

smaller drops by the action of external forces (aerodynamic and those arising in mutual collision), as well as internal forces mainly caused by the turbulence of the liquid flow in the injector. The atomization of liquid propellant is one of the pacing factors in liquid-propellant engine operation.

ATTITUDE CONTROL MOTOR. A commonly used element of spacecraft ORIENTATION systems. It is a liquid, solid, compressed-gas (pneumatic) or other type of MICROROCKET ENGINES installed on spacecraft so that the lines of action of their thrust do not pass through the spacecraft's centre of mass but at a definite distance from it. The operation of these thrust arms develops a torque that changes the angular position of the spacecraft. Triaxial orientation of a spacecraft requires from 6 to 12 attitude control motors. When 12 motors are employed, the control torque applied to each axis of the spacecraft is produced by simultaneous operation of 2 motors. The flow rate of working fluid through the attitude control motors is an important parameter of the orientation system since it predetermines the life-time of the system at a given propellant load and, consequently, the available time of the spacecraft effective operation. The flow rate of the working fluid at operation of attitude control motors depends on the value of the specific impulse, operating duty (see PULSE OPERATION), and the values of the thrust arms. Therefore the attitude control motors are placed as far as possible from the centre of mass of the spacecraft.

AURORA. Increased emissive radiation of the upper atmosphere and a complex of phenomena accompanying it. It is induced by fast protons and electrons invading terrestrial atmosphere and by rapid oscillations in geomagnetic field intensity (generation of magnetohydrodynamic waves which are absorbed in the IONOSPHERE). During aurorae, increased ionization is observed in the lower ionosphere.

At present 3 principal types of aurorae are known, which, to a certain degree, accompany each other. In the case of aurorae of 1st and 2nd types, the Earth's atmosphere at a height of 100—200 km is invaded by a tremendous quantity of electrons with energies of several keV (1st type) and protons with energies of hundreds of eV (2nd type). In the E region of the ionosphere they give rise to strong, highly non-uniform ionization and intense emission of neutral and ionized molecules and atoms of the atmosphere along with magnetohydrodynamic waves of relatively low intensity. In the case of the 3rd type of aurora, the dominant process is intense heating of the upper atmosphere by magnetohydrodynamic waves, pre-eminently with atomic oxygen emission at 6300 Å, at a relatively low intensity of invasion by low-energy protons and electrons and the weak emission created by these particles. In either case, at altitudes of less than 100 km electrons with energies of tens of keV penetrate into the D region of the ionosphere and give rise to increased ionization accompanied by intense absorption of radio waves. In the 1st and 2nd cases invasion of charged particles is greatest near 67° geomagnetic latitude. This region is called the auroral zone. It is oval in shape. Aurorae of the 3rd type are observed at much lower latitudes; prevailing in these aurorae is oxygen emission at 6300 Å. The visually observed forms of luminosity depend on the types of aurorae. The most diversified forms are witnessed in the cases of aurorae of the 1st type. The duration of aurorae

ranges from tens of min to several days. Sometimes, a few tens of min after chromospheric flares on the Sun, protons and electrons with energies of several MeV penetrate the *D* layer of the ionosphere in circumpolar zones above 67° geomagnetic latitude, increasing its ionization accompanied by absorption of radio waves; these are the so-called aurorae polares in polar ranges. The nature of aurorae is now the object of extensive investigation.

Automatic interplanetary station

AUSTRALIAN EARTH SATELLITES. *WRESAT-I*, the first Australian satellite, was launched by a US launch vehicle on November 29, 1967. Its orbit had an apogee of ~1250 km; weight, ~50 kg; operational life, 9 days. Its purpose was investigation of cosmic and solar radiation. The satellite did not separate from the upper stage of the launch vehicle, and had no attitude control; its systems and equipment were fed from chemical sources.

AUTOINFECTION. An infectious process caused by bacterial flora that is usually non-pathogenic; this flora permanently inhabits certain cavities, integuments and mucous membrane of the organism. A fact taken into consideration by aerospace medicine is the pathogenicity of human microflora that may increase due to fluctuations in resistance and immunoreactivity. Prolonged life in a spaceship cabin may cause a drop in the spaceman's immunoreactivity which may lead, in turn, to an increase in the number of pathogenic microbial forms on the skin, that may cause furuncles, abscesses, etc.

AUTOMATIC CONTROL OF PROCESS OPERATIONS. A system of instruments located at the launch complex of a space centre; it controls propellant components storage operations, joining of filling and drain lines, electric and gas connectors, fuelling and defuelling of the launch vehicle and certain auxiliary operations. Preparations for fuelling and the fuelling proper are automatic whereas defuelling is semi-automatic. The auxiliary operations are manually remote controlled. Commands are received and sent by the system of automatic control of process operations via electrical connection with the systems for launch vehicle control, propellant level check-up in the launch vehicle tanks, ground electric power equipment, launcher, transporter-erector, systems of thermostatic control, remote control of neutralization and fire protection. The permissive electrical commands are sent to the system of automatic control of process operations from the system of REMOTE CONTROL OF PROCESS OPERATIONS. The system of automatic control of process operations comprises a control console mounting the control units for various mechanisms and measurement systems, a relay cabinet, cables, etc.

AUTOMATIC EQUIPMENT of rocket engine. A system of electrical, electronic, pneumatic, hydraulic, pyrotechnic and mechanical devices ensuring automatic control of the rocket engine, i.e., ignition, starting, maintaining the predetermined performance, changing it according to the commands received, protection against external and internal disturbances, and engine cut-off.

AUTOMATIC INTERPLANETARY STATION. An automatic spacecraft designed for travel to other celestial bodies and exploration of outer space, the Moon and other planets by means of special scientific equipment. The results of these observations are transmitted to the Earth by radio systems and TV systems that transmit the images of planetary surfaces. Automatic

interplanetary stations are generally provided with astroorientation systems, and engines for trajectory correction. SOLAR BATTERIES provide the energy for spaceborne equipment. By January 1, 1968, over 45 automatic interplanetary stations had been launched, among them the Soviet *Luna*, *Venyera*, *Mars*, and *Zond* series, the American *Mariner*, *Ranger*, *Pioneer* and other series.

AUTOMATIC LAUNCH-PREPARATION SYSTEM. A composite automatic system embracing all the automatic systems that control separate units and subsystems of the launch complex, participating in erection of the space vehicle on the launcher, its mating to the umbilical connections, filling with propellants, ensuring thermostatic control and preparation of the space vehicle for launching. The automatic launch-preparation system also takes care of the storage and thermostatic control of the propellant components and their semi-automatic drainage from the launch vehicle tanks, and of the removal of the launch vehicle from the launcher. The units and systems of the automatic launch-preparation system are controlled from the central launch-preparation console, automatically or manually.

AUTOMATIC LUNAR STATION. An automatic space body designed to function on the surface of the Moon. The mission of the automatic lunar station is to explore the physical conditions on the Moon and the properties of the lunar surface. For this purpose the automatic lunar station carries various scientific facilities, radio telemetry and TV systems for transmitting to the Earth the data obtained and images of the lunar surface. The structure and equipment of an automatic lunar station must be designed for operation in the specific lunar environment. The Soviet *Luna-9* landed the first automatic lunar station on the Moon. Subsequent automatic lunar stations were landed on the Moon by the *Luna-13*, *Surveyor-1*, *Surveyor-3*, *Surveyor-5*, *Surveyor-6* and *Surveyor-7* (see SPACECRAFT and SOFT LANDING).

AUTOTROPHS. Vegetable organisms, such as algae and some species of bacteria capable of synthesizing organic materials (proteins, fats and carbohydrates) from inorganic (carbon dioxide, water, mineral salts). All autotrophs are subdivided into photoautotrophs (lower and higher) and chemoautotrophs (see PHOTOSYNTHESIS). Autotrophs transform the energy of light into chemical energy, and accumulate it in various organic compounds. In spaceships, autotrophs can effect BIOLOGICAL AIR REGENERATION and vegetable food production.

AUTUMNAL EQUINOX. The point on the CELESTIAL SPHERE where the CELESTIAL EQUATOR and the ECLIPTIC intersect and at which the Sun in its annual path passes from the Northern Hemisphere into the Southern Hemisphere (about September 22).

AVIATION MEDICINE. The branch of medicine concerned principally with the safety, health and working capacity of crew members of airplanes and other aircraft borne by aerodynamic lift force in various flight conditions in the troposphere and stratosphere.

AXES OF ORIENTATION. Three mutually perpendicular imaginary lines that intersect at the spacecraft centre of mass and are to coincide with the spacecraft axes when it is normally oriented. The axes of orientation are not associated with the body of the spacecraft and are assigned beforehand.

The axes of orientation vary according to the required type of orientation.

AXI-ECNTRIFUGAL PUMP. A pump in which an axial wheel or a screw feed is installed before the centrifugal impeller in order to improve anticavitational qualities. Serves as the main pump of rocket engines.

AXISYMMETRIC FLOW. A flow possessing symmetry with respect to the stream axis. Axisymmetrical flows include those in rocket nozzles. Axisymmetrical flow is a particular case of TWO-DIMENSIONAL FLOW.

AZIMUTH. A coordinate in the horizontal system of CELESTIAL COORDINATES: an arc of the true horizon measured from the North point on the CELESTIAL SPHERE in an easterly direction to the point where the horizon intersects the vertical passing through the given celestial body (or terrestrial object). Sometimes azimuth is measured from South to West. It is measured from 0° to 360°.

AZIMUTH ALIGNMENT. The orientation of the airframe X-axis when the launch vehicle is installed on the launcher, the vehicle being aligned in a horizontal plane to ensure the predetermined direction of the vehicle's powered flight. Azimuth alignment can be performed by turning the entire vehicle in a horizontal plane, or by appropriate orientation of individual elements of the control system on board. There are systems of automatic azimuth alignment.

B

BACKPACK. A LSS conceived in the form of a knapsack and used by spacemen for extravehicular activity and on the surface of the Moon or another celestial body. The system is completely self-contained and supports the life and activity of a spaceman wearing a pressurized space suit in conditions of deep vacuum, solar and cosmic radiation and sharp temperature fluctuations. The regeneration (air conditioning) units of the backpack purify the air of carbon dioxide, water vapours and noxious contaminants, replenish the consumed oxygen and maintain the necessary temperature. Air may be regenerated by adding oxygen stored in gaseous or liquid state in cylinders or containers; carbon dioxide and moisture may be removed by chemical (alkali, silica gel, etc.) or OXYGEN-GENERATING SUBSTANCES. In prospective backpacks, air regeneration may be based on the use of physico-chemical systems that will purify the air of carbon dioxide and moisture with the help of regeneration devices and produce oxygen from carbon dioxide and water excreted by man. The use of such backpacks will considerably prolong the time the spaceman will be able to remain in a space suit, and increase the backpack's reliability. Air is circulated in the space suit by electric fans or injectors. Normal temperature inside the suit is maintained by a temperature control system. Heat exchange between the space suit and the environment is radiation type, and therefore the optical characteristics of the space suit are of great importance. Heat abstraction from the space suit may be effected by radiation- and evaporation-type heat exchangers, by water evaporation in panels or jackets and by circulation of coolants in tubes of the cooling system.

BACTERIAL AEROPLANKTON. A community of conditionally pathogenic and saprophyte microorganisms in the spaceship cabin atmosphere. Since the source of the cabin microflora is man, the microbial composition of the bacterial aeroplankton is identical to the microflora of man's integuments and cavities. Such space-flight factors, as ionizing radiation, long-time absence of normal hygienic conditions, increased g-forces, etc., suppress the natural antibacterial resistance of the organism. In this connection the hazard of AUTOINFECTION grows up. A complex of prophylactic measured makes it possible to minimize the microbial contamination of the atmosphere of a small-volume hermetic space in which men have to stay for a long (several months) time.

BALLISTIC RE-ENTRY. The atmospheric re-entry of a spacecraft possessing zero LIFT/DRAG RATIO. The trajectory of ballistic re-entry for the given spacecraft characteristics and atmospheric parameters, known to a certain precision, is pre-computed; the RE-ENTRY ANGLE and place, ensuring landing at the specified spot, are selected proceeding from this trajectory.

BALLISTIC ROCKET. A rocket that flies over a BALLISTIC TRAJECTORY. As different from WINGED ROCKETS, ballistic rockets do not have lifting surfaces designed to create aerodynamic lift during atmospheric flight. In some cases, ballistic rockets are equipped with stabilizers for aerodynamic stability of flight. Ballistic rockets include combat missiles of various types (including intercontinental missiles), LAUNCH VEHICLES and SPACE ROCKETS.

BALLISTIC TRAJECTORY. The flight path of a body in the absence of aerodynamic lift. When ballistic rockets without lifting surfaces fly through

the atmosphere at small ANGLES OF ATTACK, lift force is negligibly small as compared with other forces (engine thrust and rocket weight); therefore they practically move along ballistic trajectories.

BALLISTITE. See HOMOGENEOUS SOLID PROPELLANT.

BAND OF NEEDLES. A band formed around the Earth by releasing a mass of thin copper or tungsten needles from the container of an Earth satellite; can be utilized as a PASSIVE RELAY STATION with omnidirectional diffusion for establishing a radio relay system of communication. Two bands of needles lying in the equatorial and polar planes at an altitude of about 4000 km are sufficient for maintaining regular radio communication between any two ground stations. Needle bands have a service life of several years. Such a band is reliable and inexpensive, but, on the other hand, diffuses only a small part of the energy of radio signals and provides a low limit speed of transmission of radio signals. Needle bands may present a danger for orbiting satellites.

BARYCENTRIC COORDINATES. The coordinates of a point measured relative to a system of coordinates whose origin lies in the center of mass of the system (barycenter). It is made use of in celestial mechanics.

BASE PRESSURE. The pressure on the base (inter-nozzle) area of the launch vehicle or on the nozzle exit. During firing, especially from a silo, the interaction of the jet efflux with the deflector may increase the base pressure considerably, and this may cause a collapse if protective measures are not taken. When a launch vehicle flies near the Earth, the inducing effect of jet streams keeps base pressure below ambient. At high altitudes and in vacuum, base pressure is higher than ambient (base effect) which increases thrust.

BAYKONUR. One of the largest space centres in the Soviet Union. It is situated in the Karaganda Region of the Kazakh SSR. The Baykonur range extends for thousands of km over the USSR territory and terminates in the Pacific Ocean aquatory. Built at Baykonur is a number of launch complexes, maintenance areas, and tracking stations for the realization of an extensive space research program. A number of tracking stations are also located along its ranges. Baykonur was the site from which *Sputnik-1*, the world's first man-made Earth satellite, was launched into space. It was from Baykonur that the world's first manned space flight was made by Yuri A. Gagarin, that the world's first spacewoman Valentina V. Tereshkova was sent into orbit, and that many other launches for space research were accomplished. A series of manned spaceships, a number of space stations, and numerous artificial Earth satellites of various types roared off from the Baykonur space centre. Baykonur was also the launching area from which the Moon, Mars, and Venus probes were repeatedly and successfully blasted off.

BELYAYEV, Pavel Ivanovich (born 1932, Chelishchevo, Vologda Region). Pilot-cosmonaut of the USSR, colonel. Hero of the Soviet Union. Member of the CPSU since 1949. On graduation from secondary school in 1942, worked at a factory. Volunteered for service in the Soviet Army in 1943. Entered the Yeisk School for Navy Fighter Pilots and graduated in 1945. Participated in the war with Japan. In 1956 entered the Air Force Academy and graduated in 1959. Belyayev was the commanding officer of the space flight he made together with A. A. LEONOV on board the satellite-spaceship *Voskhod-2*.

The spaceship he piloted was sent into orbit on March 18, 1965. It circled the Earth 17 times and covered over 720,000 km in 26 h. During the landing, P. Belyayev employed the manual control system.

BEREGOVOY, Georgi Timofeyevich (born 1921, Fyodorovka village, Karlovsky District, Poltava Region). Pilot-cosmonaut of the USSR. Major-general. Twice Hero of the Soviet Union. Merited Test Pilot of the USSR. Member of the CPSU since 1946. Graduated from an incomplete secondary school, an aeroclub and the Lugansk School for Air Force Pilots. During World War II, piloted an attack aircraft, commended for courage and heroism. After the war, graduated from a higher school for officers and courses for test pilots. In 1956 he graduated the correspondence department of the Air Force Academy now known as the Gagarin Academy. He was a test pilot from 1948 until 1964, when he was enlisted in the group of cosmonauts. On October 26—30, 1968, Beregovoy made a space flight in the *Soyuz-3* spaceship. He orbited the Earth 64 times, covering a distance of more than 2,600,000 km in 94 h 51 min. During this flight the *Soyuz-3* was repeatedly manoeuvred and approached the unmanned *Soyuz-2* twice.

BERYLLIUM, Be. A highly effective fuel for rocket engines. A silver-gray metal; density, 1.82 g/cm^3 at 20°C; m.p., 1284°C; b.p., 2970°C; ignites with difficulty. Can be used profitably only with oxygen oxidizers. Proposed by GDL (1930) for use with oxygen together with liquid HYDROGEN, high-boiling fuels and in gunpowder with a view of considerably increasing the efficiency of the rocket propellant. It was tested in the form of a suspension; is used in heterogeneous (composite) solid propellants. Beryllium and its combustion products are very poisonous. Potentially important for rocket and space technology as a structural material with a high strength-to-weight ratio.

BERYLLIUM HYDRIDE, BeH_2. A potentially possible highly effective fuel for rocket engines. A solid, density 0.64 g/cm^3, stable at temperatures up to 240°C. Resistant to the action of dry and humid air at temperatures up to 200°C. Theoretically, the SPECIFIC IMPULSE developed by the high-boiling propellant consisting of HYDROGEN PEROXIDE and beryllium hydride (calculated without taking into account the losses due to the two-phase composition of the flow of the combustion products) is almost equal to the specific impulse of one of the most effective cryogenic propellants, that consisting of liquid fluorine and liquid hydrogen. Beryllium and its compounds, including those in the combustion products, are highly poisonous. Can be obtained, for example, by thermal decomposition of beryllium-organic compounds.

БИ-1 (BI-1). A rocket aircraft, the first Soviet aircraft to have a liquid-propellant rocket engine (see Д-1-А-1100). This low-wing monoplane had a take-off weight of 1.5 t, including 500 kg of propellant (nitric acid + kerosene). Its wing span was 7.5 m. It was designed by A. Y. Bereznyak and A. M. Isayev in 1941—42 under the supervision of Chief Designer V. F. Bolkhovitinov. Piloted by G. Y. Bakhchivandzhi, the *БИ-1* made first test-hops on May 13, 1942, the maiden flight on May 15, 1942. In 1942—43 the *БИ-1* made several flights at a speed of up to 800 km/h, this signalizing the dawn of Soviet jet aviation.

BIOCHEMICAL COMPOSITION OF PLANTS. The content of vitally important substances (proteins, carbohydrates, fats, vitamins, minerals, water, etc.) in vegetable tissues. Plant classification is according to content of proteins (peas, beans, soybeans, etc.), carbohydrates (sugar and beetroot, carrots, potatoes, rice, etc.), oils (sunflower-seed, peanuts, etc.), vitamins (spinach, sorrel, parsley, onion shoots, etc.). Depending on the biochemical composition of plants cultivated in the life support system, various space farms (greenhouses) can be designed on the basis of the biological recycling of substances.

BIOCOMPLEX. Specific and numerical composition of preselected POPULATIONS of vegetable and animal origin on board the spaceship, which ensure reliable functioning of its biotechnical system. Depending on the type of the biotechnical system (open, semi-closed or fully closed), the biocomplex may include lower and higher plants and animals, as well as microorganisms. Man is also a member of the biocomplex. When composing a biocomplex, biological compatibility of the living organisms constituting it must be ensured; man and the other members must be provided with food, water and an atmosphere of adequate composition; waste of the organisms' vital activity must be processed into products convenient for use by other biocomplex members; the rate of metabolism must be coordinated and have no impasses; the minimum requirement for each of the environmental factors and technical means necessary for the normal vital activity of each biocomplex member must be met; stable and reliable functioning of the whole complex in case of possible change in environmental factors during the space flight must be provided.

BIOFILTER. A biological oxydation device for mineralization of organic constituents of sewages with the aid of aerobic microorganisms growing on the surface of a porous filtering material. Biochemical oxidation is ensured by oxygen of air circulating due to the difference in temperature in the filter and in the surrounding medium. Biofilters with forced air circulation are termed aerofilters. The operating principle of biofilters (aerofilters) may be employed in units for biological mineralization of mixtures of solid and liquid waste in LSS of spaceship during long-term space flights.

BIOINDICATORS. Biological objects (microbes, plants, animals) participating in a space flight in a new orbit, in a new spaceship or under special conditions with the purpose of studying biological factors of outer space (prior to manned flights), carrying out biological evaluation of a LSS and choosing biological alarm indicators. Before the first manned space flight repeated flight experiments on animals were carried out. The flight of dogs on *Cosmos*-110 satellite was also a biological reconnaissance of new orbits crossing the radiation belts of the Earth, as well as testing of new methods of space exploration. The selection of reliably functioning bioindicators involves the development of instrumentation for long-time recording of biological processes. The 2nd Soviet satellite-spaceship had a biological element which indicated pressure changes in a capsule containing microbes; these data were used to analyse the changes in the microorganisms' life activity. To carry out prolonged experiments on animals, implantable sensors have been developed; these sensors are to provide radio transmission of

data obtained through intact skin in conditions of animals' free behaviour. Combination of bioindicators with a medical data management system will enable one to design a system for biosignalling, i.e. transmission of urgent information from the Earth or the spaceship crew on situations unfavourable or dangerous for man's life.

Biological air regeneration

BIOLOGICAL AIR REGENERATION. Continuous restoration of the optimum atmosphere in the spaceship sealed cabin owing to the activity of autotrophic organisms (algae, higher plants, chemosynthesizing bacteria) capable of photo- and chemosynthesis. Regeneration of air is necessary to provide the spaceship crew and BIOCOMPLEX with oxygen obtained from carbon dioxide and water vapours excreted by the biocomplex members. The advantage of the biological regeneration method is the organic link between all biocomplex members and autotrophic organisms; the biomass of the latter, in particular, may be used to feed other biocomplex members, while the biological waste is utilized in the autotrophic link of the LSS.

BIOLOGICAL EFFECT of cosmic radiation. The relative degree of danger offered for spacemen by various constituents of cosmic radiation is not equal, and may change depending on the flight duration and trajectory. In short-time flights the most important are protons, the exposure to which is possible during crossing the radiation belts of the Earth or during solar flares. The radiation injuries caused by protons with energies of 100 to 600 MeV do not differ substantially from those caused by X-rays and gamma radiation, since the relative biological effectiveness of protons is 1.0. In longer duration space flights, of great importance become heavy ions, whose relative biological effectiveness is much higher than 1.0.

BIOLOGICAL RHYTHMS. Periodicity of onset and cessation, intensification and subsidence of various processes in the organism. Biological rhythms associated in their duration with geographic cycles (alternation of seasons, day and night) are termed ecological rhythms (seasonal, daily, tidal, lunar, etc.). The dependence of biological processes on alternation of daylight and darkness during a 24-hour period is termed photoperiodism. The environmental temperature is of less importance, though its rise somewhat shortens the duration of biological cycles. Some 40 human functions (pulse, body temperature, respiration, diuresis, etc.) are known to have daily rhythm. Maintenance of normal biological rhythms ensures correct course of all physiological processes. The studies of biological rhythms and their dependence on environmental conditions are of great importance for space exploration.

BIOLOGICAL SATELLITE. A satellite for medico-biological investigations connected with space flight. Such a satellite carries experimental animals and other living organisms—plants, bacteria, etc. Examples are the Soviet satellite *Cosmos-110* and the American *BIOS*. Sometimes medico-biological investigations are carried out on satellites having a different main purpose, e.g., on the Soviet satellite-spaceships which were launched to open the way for the first manned flights in space.

BIOLOGICAL SYNTHESIS. Production of composite organic substances from simpler ones by metabolism of living vegetable or animal organisms. In vegetable organisms biological synthesis takes place in the course of PHOTOSYNTHESIS, while in animal organisms, at the expense of the

energy liberated in the process of dissimilation of organic compounds in the organisms. Biological synthesis is dependent on the environment and is closely connected with the decomposition of substances taking place in the organism simultaneously with the synthesis. Biosynthesis is of great importance in development of spaceship LSS.

BIOLOGICAL WASTE. Substances excreted by man and other biological objects to the environment in the process of metabolism. The quantity and composition of biological wastes are closely connected with the environmental conditions and food consumed. The chemical composition of biological wastes is extremely complicated; e.g., urine contains over 180 different substances. In all biological waste the quantity of water in relation to the total weight is up to 99%, and this is of vital significance when designing the water regeneration system for sustained space flight.

BIOMASS. The amount of living organism substance per unit of the cultivation area (usually per 1 m^2) or volume of water (per 1 or m^3) expressed in weight units (g). The composition of the BIOCOMPLEX permits replenishment of the food rations of man and other living organisms during space flight with the biomass of algae, yeasts, etc.

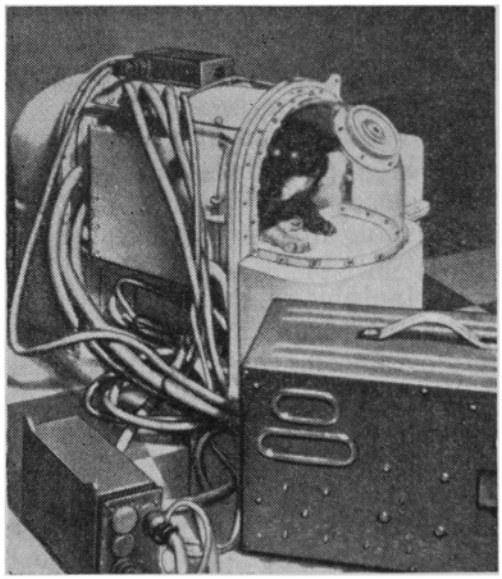
BIONICS. A field of science using structural principles of biological systems for solving technical problems. The development of means of orientation, navigation, location, the designing of complex automatic control systems, more sensitive sensors, etc., requires simpler and more reliable solutions, which may be often found in living organisms. The development of bionic-type systems is of extreme necessity for space exploration. In particular, of great importance is the development of devices for recording extremely weak magnetic, acoustic, electric and other impulses, designing of artificial olfaction systems, etc. The development of self-adjusting, interference-resistant navigation and control devices would be also impeded without studying respective biological analogues. The problems of biological control, optimization of communication between the operator (spaceman) and spaceship systems are bionic problems, since it is necessary to "teach" the technical devices to "understand" the "language" of biological systems. The development of fully closed ECOLOGICAL SYSTEMS for spaceships involves imitation of material and energy communications between man and nature, organic and inorganic world. In this case it is also necessary to use the principles of bionics and to choose the most rational and successful solutions offered by living nature for their realization by engineers.

BIOSPHERE. A sphere of the Earth inhabited by living organisms. The biosphere consists of the Earth's water cover (hydrosphere), the upper part of the Earth's crust (lithosphere) and the lower part of the atmosphere. All microorganisms, plants and animals known on the Earth dwell within the biosphere. The circulation of matter here is effected with participation of living organisms and has a character of biogeochemical transformations. The biological reproduction of man's food on board a spaceship may be effected with the use of partially or fully closed system of RECYCLING OF SUBSTANCES.

BIOTECHNICAL SYSTEM. A space-borne system consisting of a BIOCOMPLEX composed in accordance with the space flight mission and duration,

and technical means ensuring optimal conditions for biocomplex functioning. The technical means of a biotechnical system include units for light emission and distribution, power supply and thermal control, as well as space farm, kitchen, blocks for biological and physico-chemical regeneration of air and water, blocks for MINERALIZATION of waste, etc.

BIOTELEMETRY, biological telemetry. Remote measuring of biological functions; a principal method for examining man and animals in space flight conditions. The characteristic features of space biotelemetry are the necessity of date transmission through very long distances; the discrete character of the transmission, depending on the orbit parameters and geographic disposition of receiving stations; the limited transmission capacity of the communication channels; the simultaneous transmission of a great number of data; the necessity of collecting information in conditions of the spaceman's normal activity, etc. A biotelemetry system consists of the information source (spaceman, sensors, spaceborne medical instrumentation); the amplifying, transmitting and receiving units and the information consumer (indicators and recorders, a physician). Of serious importance is the problem of noise, which may distort the information transmitted, as well as the problem of coordinating the volume of the data to be transmitted with the transmission capacity of the communication channel. To transmit physiological data, channels with a transmission capacity of 0.1 to 40,000 bit/sec are necessary. In order to employ standard telemetry channels, methods of signal concentration (e.g., by transmitting only the most important parts of communication) and commutation of several slowly-changing parameters upon one telemetry channel are used. The problem of optimum loading of telemetry channels is of still greater importance in connection with the increasing of the duration and the distance of space flights. In such flights the information will be "concentrated" by automated data processing systems on board the ship.



A container with various transducers and supply lines for scientific research and food supply.

BIPROPELLANT. A propellant for liquid-propellant and hybrid rocket engines, consisting of two separately stored components: the OXIDIZER and the FUEL. Bipropellants are chiefly used at present in liquid-propellant engines. The advantages over other propellants are: less explosion hazard, wider choice of oxidizer and fuel. The principal bipropellants are: nitrogen tetroxide or nitric acid and unsymmetrical dimethyl hydrazine; LOX and kerosene; LOX and liquid hydrogen; liquid fluorine and liquid hydrogen, etc.

BLAGONRAVOV, Anatoli Arkadyevich (born 1894). Soviet scientist in mechanics, academician since 1943. Hero of Socialist Labour. Member of the CPSU since 1937. Graduated from the Mikhailovskoye Artillery School in 1916, the Higher Artillery School in 1924, and the Military Engineering Academy in 1929. In 1938 he became a professor of the Artillery Academy in Moscow. Since 1953, he has been Director of the Institute of Machine Studies of the Academy of Sciences of the USSR. Blagonravov's scientific works are devoted to mechanics and armaments. He conducts extensive scientific and organizational work as Chairman of the Commission for Exploration and Utilization of Outer Space of the Academy of Sciences of the USSR. Since 1959, he has been Vice-President of the Committee on Space Research.

BLOOD OXYGENATION CAPACITY. Amount of hemoglobin capable of binding oxygen. Each gram of hemoglobin can bind 1.36 cm^3 of O_2. Hence, the oxygenation capacity of blood containing 0.14 g of oxygen per cm^3 of hemoglobin is about 0.19 cm^3 of O_2. The normal oxygen content of blood reaches 20% of its volume, 0.3% being dissolved oxygen. Practically all oxygen carried by the blood (18.7%) is combined with hemoglobin and forms oxyhemoglobin (HbO_2), a readily dissociating compound. When fully saturated with oxygen, human blood containing 600—700 g of hemoglobin can bind approximately 1 l of O_2 (see HYPOXIA).

BOLIDE. A very bright and large METEOR. Bolides are frequently accompanied by sounds resembling thunder and the fall of meteorites.

BOOSTER ROCKET ENGINE. A rocket engine used to assist and accelerate the take-off of an aircraft or rocket and frequently jettisoned after burnout.

BOOST PUMP. An auxiliary pump in the system that feeds the propellant or working fluid from the rocket tanks into the rocket engine and increases the inlet pressure of the engine's main pump. There are jet, axial (helical), and centrifugal boost pumps. A boost pump is installed in the propellant tank, right under it, or in front of the main propellant pump. The boost pump can also be built into the main pump.

BORMAN, Frank (born 1928, Gary, Indiana). American astronaut, colonel of USAF. He graduated from the Military Academy in 1958 and became an Air Force pilot, underwent training at the Williams Air Force Base. Between 1951 and 1956 served in various Air Force units. In 1957 he graduated from the California Institute of Technology and in 1957—60 taught thermodynamics and fluid mechanics at the US Military Academy. In 1960 he graduated from the USAF Aerospace Research Pilots School and later became an instructor there. He joined the group of astronauts of the NASA in 1962. Together with G. LOVELL made a space flight as commanding officer of *Gemini-7*. *Gemini-7* was placed in orbit on December 4, 1965, and in 14 days (330 h) made 206 revolutions round the Earth. Together with G. Lovell and

W. ANDERS made a flight round the Moon as commanding officer of *Apollo-8*. The spaceship was launched on December 21, 1968, made nearly 2 revolutions around the Earth, entered a celenocentric orbit on December 24, and on December 25, after completing 10 orbits around the Moon, changed the flight path to return to the Earth and made a splash-down in the Pacific, near Christmas Island, on December 27.

BORON HYDRIDES (boranes). Fuels for rocket engines; compounds of boron and hydrogen, e.g., diborane (B_2H_6), pentaborane (B_5H_9) and others. Boranes were proposed as fuels for liquid-propellant engines by Y. V. Kondratyuk in 1929.

BRADYKINESIA. General retardation of motions; slow, smooth motions observed in spacemen during the flight and connected with the state of WEIGHTLESSNESS. During a space flight bradykinesia may lead to changes in the musculoskeletal apparatus and to hypokinesic sickness.

BRAKING of the reactive gyrating masses. See SUPPRESSION OF KINETIC MOMENT.

BRAKING PULSE. A pulse that is imparted to the spacecraft in the direction opposite to that of its orbital velocity. Such a pulse is supplied, for example, when correcting the orbital period of a satellite in order to make this period shorter (see CORRECTION OF ORBIT).

BRAUN, Wernher von (born in 1912). Scientist in rocketry. Born in Germany. Attended the Zürich and Berlin Institutes of Technology and Berlin University. Began research in liquid-propellant rockets in 1930. In 1934 launched two liquid-propellant rockets (*A-2* type) that reached an altitude of 2.5 km. Beginning with 1937 was one of directors of the German Rocket Research Centre in Peenemünde. His work was closely linked to the plans of the Hitlerite General Staff in World War II. Chief designer of the *V-2* missile fired against the UK and Netherlands. In 1945 he went to the USA to head the US Army Rocket Research and Development Centre, Fort Bliss, Tex. Later, consultant on launching of rockets at the White Sands Proving Grounds, N. Mex., and director of Development Operations of US Army Ballistic Missile Agency, Ala. Appointed in 1956 director of programmes for *Jupiter* intercontinental ballistic missile and *Explorer* satellites. Directed the *Saturn* launch vehicle and *Apollo* spaceship development programmes. In 1960 he became a leader of NASA and director of the NASA Marshall Space Flight Centre. Among his books on space flight are: *Das Marsproject* (1952), *Across the Space Frontier* (1952), *Space Medicine* (1952), *The Conquest of the Moon* (1953), *Station in Space* (1953), *The Exploration of Mars* (1956, W. Ley, co-author), *Project Satellite* (1958), *First Man to the Moon* (1960).

BREATHING APPARATUS. Apparatus for inhaled air enrichment with oxygen. Different apparatuses deliver oxygenated air to the lungs at environmental pressure or at over-pressure; the types are air-borne, i.e., stationary, portable, or parachute-borne.

BREMSSTRAHLUNG. The short-wave radiation that arises at retardation of corpuscles in the spacecraft shell. At collision with the spacecraft and penetration into its shell, the corpuscles (e.g., electrons or protons) interact with the material of the casing, are retarded, and their kinetic energy is converted into the energy of X-rays that are dangerous for the health of the space-

men. The greater the mass of the corpuscle, its velocity and the atomic weight of the material of the spacecraft shell, the greater the bremsstrahlung it causes.

BRITISH EARTH SATELLITES. The first satellite, *Ariel-I*, was designed with US collaboration, and launched on April 26, 1962, by an American launch vehicle; it weighed 133 kg; its orbit had an apogee of ~1200 km, its mission was exploration of the ionosphere, charged particles and short-wave radiation of the Sun. The satellite was un-oriented; the energy supply was from solar batteries. *Ariel-II* was launched on March 27, 1964, and *Ariel-III* on May 5, 1967, by the *Scout*, an American launch vehicle. Their characteristics were: weight, ~90 kg; mission, study of the ionosphere and radio noises at various frequencies; stabilization, by spin; energy supply, from solar batteries.

BRITISH INTERPLANETARY SOCIETY. A public body founded in 1933. As early as in 1936 its membership swelled to 100. The same year a Technical Committee was set up under the Society, with the object of designing spaceships and their systems. In 1939 the Society members worked out in detail the design of a spaceship carrying a crew of 3 intended for a 20-day lunar expedition. Since the war, research groups were formed with the object of investigating various problems of space flight: design of space stations, astronauts' space suits, orbital rendezvous and refuelling, use of nuclear power in rocket engines, establishment of global communications via satellites in synchronous orbits, etc. In 1950 the 1st International Astronautical Congress sponsored by the British and German Interplanetary Societies, was held in Paris. The 2nd congress in London adopted the statute of the International Astronautical Federation, modelled on that of the British Interplanetary Society. According to the statute, the aim of the International Astronautical Federation is to promote the development of space flight, interplanetary research and space communications by carrying out investigations, publication of discoveries and international cooperation in the field of space flight. The Society publishes the *Space Flight* magazine, does extensive work in popularizing knowledge related to space flight, and arranges symposia on special subjects.

BRITISH ROCKET ENGINES. Extensive development of rocket engines was started in Britain after World War II. Auxiliary rocket engines were developed for aircraft (jet assisted take-off units and boosters) and missiles. Batch production has been started of Bristol Siddley *Gamma* and *Stentor* liquid-propellant engines firing a hydrogen peroxide and kerosene propellant to power the *Black Knight* and *Blue Steel* rockets (*Gamma-301* develops a thrust of 10.8 t, and the twin-chamber *Stentor*, 7.2 to 1.8 t). The experimental liquid-propellant engines are more advanced: Bristol Siddley *BS. 625* (twin-chamber; thrust 2×3.5 t; specific impulse in vacuum, 265 s; weight, 168 kg; to be used in the 2nd stage of the *Westland* rocket; and *BS. 606* (eight-chamber; thrust, 8×2.8 t; assembly weight, 506 kg; used for the same rocket's 1st stage); they also fire hydrogen peroxide and kerosene; Bristol Siddley *BS. 613* firing LOX and liquid hydrogen; Rolls-Royce *RZ-2* for the *Blue Streak* intermediate range ballistic missile (two chambers, with a thrust of 68 t each; burning time, 150 s; weight, 2×680 kg; diameter, 1130 mm; chamber pressure, about

40 at, propellant, LOX and kerosene); *RZ-2* engine is to be used in the 1st stage of the *Europa-1* launch vehicle. The solid-propellant engine Bristol *Raven-2B* is batch manufactured on licence from Aerojet-General Corp., USA. It has a thrust of 8.1 t; burning time, 20 s; dia, 430 mm. It propels the *Black Knight* and *Skylark* missiles.

BUBBLING of gas through propellant. Passing of compressed gas through a layer of propellant for the purpose of mixing it in the ground-based or launch vehicle's propellant tanks at the space centre. In long-term storage in propellant-loading tanks or on prolonged standing of the fuelled launch vehicle at the launching site, the layers of the propellant, as a result of heat exchange with the environment and convection, assume different temperatures. In high-boiling propellants the warmer layers are at the top of the tank, whereas the colder layers are at the bottom; in cryogenic propellants, on the contrary, the lower layers of the propellant under additional pressure of the head of liquid above them have a higher boiling point than the top layers with boiling points corresponding to the pressure in the ullage above the level of the propellant in the vessel. The transfer of heat through the walls of the container, in this case, results in evaporation in the top layers and an increase in the temperature of the bottom layers of the liquid up to the new boiling point. For precise determination of the weight of the propellant loaded by volume it is necessary to know its density which depends on the temperature; bubbling of gas through the propellant equalizes the temperature. The gas passing through the liquid causes artificial boiling and mixes the propellant. Mixing can also be accomplished by means of a pump; in this case the pump removes the propellant from the tank and returns it to the same tank. Bubbling is discontinued when the telethermometers fixed at different points of the tank show the same temperature.

BURNING RATE OF SOLID PROPELLANT. The rate of transfer of the burning surface of the CHARGE of solid propellant (linear rate), or the mass of the propellant burning per unit of burning area per unit of time (mass rate). The burning rate is one of the basic parameters of solid propellants. It depends on the chemical composition of the propellant, the size of the engine, initial temperature of the propellant, and, for heterogeneous propellants, also on the grain size of the oxidizer and the thoroughness with which the components have been pre-mixed. The burning rate increases with an increase in pressure (only in a limited range it does not depend on it) and with an increase in the density of the flow of combustion products over the combustion surface (EROSIVE BURNING). Since the gas pressure in the combustion chamber is proportional to the mass burning rate, its considerable dependence on the pressure and the initial temperature of the propellant results in considerable scatter in the values of the thrust produced and the burning time, and also to impairment of other parameters of the solid-propellant engine, which is extremely objectionable.

BURNOUT WEIGHT. The weight of the rocket at the moment its engine (or the engine of one stage) is cut off. In addition to the weights of the PAYLOAD (or of the next stages in case of a multistage rocket) and the structure, the burnout weight includes the weight of the propellant residue the bulk of which usually consists of the standby propellant.

BURNTHROUGH OF ENGINE COMPONENTS. Formation of defects on the walls of the thrust chamber, gas generator of a rocket engine, gas ducts, etc. (holes or meltings), under the effect of products of propellant combustion. If developed, burnthroughs may cause the rocket engine to fail.

BYKOVSKY, Valeri Fyodorovich (born 1934, Pavlov-Posad, Moscow Region). Pilot-cosmonaut of the USSR, colonel. Hero of the Soviet Union. Member of the CPSU since 1963. He graduated from the Moscow Air Club Flying School, the Kachinsk Air Force Flying School (1955), and the Air Force Engineering Academy in Moscow (1966). Was an Air Force pilot. On June 14—19, 1963, on board the *Vostok-5* spaceship Bykovsky orbited the Earth 81 times and covered over 3,300,000 km in 119 hours. On June 16, V. Bykovsky began a group flight with the *Vostok-6* spaceship piloted by V. V. Tereshkova. Two-way radio communications were established between the cosmonauts. TV broadcasting was effected from both spaceships.

C

CABIN ATMOSPHERE. The artificial gaseous environment in a SEALED CABIN. The cabin atmosphere that is the best for man is the one that completely corresponds in physical properties and chemical composition to the Earth's atmosphere. However, when the cabin is depressurized for man's exit into the outer space or on other celestial bodies, the cabin atmosphere may differ substantially from the Earth's atmosphere. The cabin atmosphere may consist of a single gas, e.g. gaseous oxygen at a pressure of 250—420 mm Hg, or of several gases (O_2, N_2, CO_2, and others). The advantage of the single-gas cabin atmosphere is that it diminishes the possibility of decompression sickness and decreases the effect of cabin depressurization when the spacemen exit into outer space or land on another celestial body. However, when making use of a single-gas cabin atmosphere, it becomes necessary to reduce the barometric pressure as compared to that of the Earth's atmosphere and to raise the partial pressure of oxygen (see OXYGEN, MEDICAL-GRADE) which increases the fire hazard. 3 American astronauts (V. Grissom, E. White, R. Chaffee) perished while training in an *Apollo* capsule on January 27, 1967. The fire resulted from some failures in the space cabin filled solely with oxygen. Besides, when the cabin atmosphere consists of a single gas the temperature control system becomes more complicated. Under the effect of a prolonged (more than 2 or 3 weeks) exposure to the action of a single-gas cabin atmosphere, certain undesirable changes are observed in the physiological functioning of man, which lower the resistance of the organism to the space flight factors, and for this reason the use of single-gas cabin atmospheres is not permissible in long-term flights.

A multi-gas cabin atmosphere consisting of O_2, N_2 and CO_2, at normal barometric pressure is superior to others. However, in long-term space flights certain deviations from the Earth's atmosphere may occur. The barometric pressure in the cabin may vary within 300—900 mm Hg. The partial pressure of oxygen should be 150—300 mm Hg; an oxygen pressure below 150 mm Hg may result in the manifestation of signs of anoxia, a decrease in the resistance of the organism to the adverse effects of space flight factors, and a diminished working capacity of the crew members. If, in a long-term flight, the pressure exceeds 300 mm Hg, this can result in pronounced changes of the respiratory organs, cardiovascular and hemopoietic systems and decrease the resistivity of the organism. The partial pressure of carbon dioxide should not exceed 7.6 mm Hg, which corresponds to a concentration of 1% (by volume) at normal barometric pressure; a concentration of CO_2 exceeding 1% has a deleterious effect on the organism, causing dyspnea, hyperpnea, a sensation of heaviness, sometimes headache, while a concentration of 3% causes general weakness, intensification of the headache, tachycardia and high arterial pressure, a sharp drop of working capacity. The nitrogen content should be approximately 78% (by volume), its partial pressure, 590 mm Hg. The physiological importance of nitrogen for living organisms is as yet insufficiently known. Nitrogen is the diluent gas which, probably, reduces the rate of oxidation processes in the organism. In certain cases this may be a positive compensatory reaction. Works of Prof. M. I. Volsky showed that nitrogen was necessary for normal course of all life processes in the organism. Elimination of nitrogen from the cabin atmosphere leads to a reduction in the

barometric pressure, and consequently to harm of the organism. If technically necessary, it is probably possible to reduce the partial pressure of nitrogen to some degree. In future nitrogen may probably be substituted by some other inert gas, e.g., helium which is 7 times lighter and more heat-conducting; this makes it possible to raise the temperature in the cabin and to reduce the capacity of the temperature control system. However, the viscosity of helium is lower, it is more fluid (the prevention of leaks in the cabin is more difficult). It has been proved experimentally that a man can remain in a helium, to be more exact, a helium-oxygen environment, for a short time (up to 10 days); the danger of decompression illness on cabin depressurization is less in this case and elevated temperatures in the cabin are more easily endured. For a person in a helium-oxygen environment the optimum temperature is 3.5—6.5°C higher and the voice timbre 0.7 octave higher. The question whether a helium-oxygen cabin atmosphere can be used, needs to be studied more completely. It is necessary to maintain in the cabin atmosphere: a humidity of 30—70% at a temperature of 20 ± 5°C, gas flow velocities not exceeding 0.2—0.3 m/s, rate of pressure changes in the process of regulation, etc., not more than 2 mm Hg/s. All the physical properties of the cabin atmosphere as well as its chemical composition are maintained with the aid of the LSS.

CABIN HABITABILITY. Possibility of sustained existence and activity of man and the BIOCOMPLEX in the sealed cabin of a spaceship. The principal conditions for cabin habitability are: maintenance of an artificial atmosphere approximating that on Earth, by means of the LSS (see CABIN ATMOSPHERE); meeting the man's requirements for provisions of food and water, disposal of biological wastes, etc. The interior of the cabin and an efficient system of communication with Earth are important for cabin habitability.

CABLE MAST. An element of a launcher of launch complex; a mast-like metal structure used for bringing cables and ground members of plug connectors of the ground electric system to the launch vehicle plug connectors. The cable mast brings the cables, as a rule, to the 2nd and following stages of the launch vehicle; however, it may become necessary to bring the electric power to the 1st stage of the launch vehicle if its on-board plug connectors are located on the side surface of the airframe instead of its end. The cable mast is either hinged on the launch system (throw-off mast) or secured to it rigidly (stationary mast). In the former case the mast is thrown to a certain angle away from the launched vehicle, withdrawing the breakaway plug connectors and giving room for the launch vehicle to lift off; the thrown-off mast falls onto a hydraulic shock absorber. In the latter case the cable mast is secured rigidly in a vertical position on the launcher and the cables with the ground members of the plug connectors are brought in at different levels over the mast arms to the plug connectors of the launch vehicle. In the course of launching, special drives throw off or turn the arms with plug connectors from the launch vehicle, clearing the room for the lift-off. In this case the cable mast is positioned at a safe distance from the launch vehicle. Sometimes the cable mast and its plug connectors are joined with the launch vehicle in the vehicle assembly building and, consequently, are brought to the launch site together with the launch vehicle. After the erection of the vehicle on the launcher the

Calibrated propellant load

lower end of the cable mast is hinged on the mast support. Quite often the cable mast is used for bringing-in the propellant-loading lines too, in which case it is referred to as umbilical tower.

CALIBRATED PROPELLANT LOAD. The mass of liquid propellant required for powered flight of a rocket or a rocket stage in case of undisturbed motion, at the rated parameters of the rocket (weight, engine thrust, etc.).

CAMERA TRACKING STATION. Intended for filming the launch vehicle during the POWERED-FLIGHT phase. Since the spatial attitude of the cinetheodolite lens axis in the tracking period is continuously recorded, the interpretation of the film shot allows to determine many parameters of the launch vehicle's flight path. Space centres are provided with a network of camera tracking stations whose operation is synchronized by the common timing system.

CANADIAN EARTH SATELLITES. *Alouette-I* (launched September 29, 1962) and *Alouette-II* (launched November 29, 1965) were designed with US co-operation for investigation of the ionosphere. The *Thor-Agena*, a US launch vehicle, was used. Their characteristics were: maximum apogee: ~3000 km; weight: 145 kg; body dia: 1.07 m; orientation: none; energy supply: from solar batteries on the body surface. The 3rd satellite, *ISIS-A*, went up on January 30, 1969, from the Vandenberg Air Force Base (USA); its mission was exploration of the upper layers of the atmosphere.

CANCELLATION OF COMMANDS. Return of control circuit elements to initial positions. Commands are cancelled in the systems of launch complex and launch vehicle in case of failure of a component if this can cause improper implementation of the entire operation.

CAPSULE. One of the names for the re-entry body of American spaceships.

CARBON DIOXIDE CONCENTRATION. Carbon dioxide is removed from the spaceship CABIN ATMOSPHERE for subsequent utilization. In some LSS, it is practicable to use the carbon dioxide exhaled by the crew for oxygen recovery. In air scrubbing systems, when adsorbents are regenerated, mixtures of carbon dioxide and other substances are obtained. Carbon dioxide can be concentrated by freezing or sorption with subsequent desorption of saturated carbon dioxide, or by successive saturation of one and the same sorbent (hypersorption) with subsequent desorption of carbon dioxide by heating or some other method.

CARDIOVASCULAR SYSTEM in space-flight conditions. In the pre-launching period certain reflectory changes due to excitation of the sympathetic division of the vegetative nervous system can be observed. The heart rhythm is accelerated, the heart contractions become more intense, and the arterial pressure rises. In the POWERED-FLIGHT PHASE the g-force causes mechanical displacement of the heart (determined by a change of the heart's electric axis) and a number of changes in the pulmonary circle. The blood becomes congested in the pulmonary vessels, thus causing a retardation in blood flow and a drop in the volumetric content of oxygen in the blood. The course of certain reflexive actions, e.g., reflexes from the receptor zones of the pulmonary and carotid arteries, is disturbed. In conditions of WEIGHTLESSNESS the reactions of the circulatory system are of a phase nature. Slower normalization of the pulse is typical of the transitional phase. In this phase other

changes, due to the preceding action of g-forces in the powered phase of the flight, are also observed. Within 2—4 h a phase of incomplete adaptation to weightlessness sets in. During this phase various reactions by the cardiovascular system, vestibular apparatus and other organs may be observed. These reactions are due to the instability of the regulating mechanisms, and their re-adaptation to a new functional level. Within 12—16 h a phase of gradual stabilization of cardiovascular reactions sets in (phase of relatively stable adaptation). In the course of flights lasting many days, the adaptation of the cardiovascular system to conditions of weightlessness remains steady. However, irrespective of the flight duration a "return" reaction is observed before landing, this reaction being characterized by pronounced emotional excitation. During re-entry, the spaceman is subjected to g-forces after a long time of weightlessness and his tolerance to them is diminished. Post-flight examinations reveal vascular instability and a drop in the vascular tonus and arterial pressure. In weightless condition, "space arhythmia" has been noted in spacemen. The instability of the pulse rate is caused by increased vagal tonus. This, in turn, is due to changes in the nervous regulation associated with re-adaptation of the functioning of the entire organism. Of principal importance here is the reflex of "relief" due to lower demands on the cardiovascular system in weightless conditions (lower energy consumption for maintaining the muscular tonus; absence of the gravitational factor in blood circulation). The cardiovascular system is a very precise and sensitive indicator of various functional changes caused by space flight factors.

CARPENTER, Malcolm Scott (born 1925, Boulder, Colorado). American astronaut, lieutenant-commander in the USNavy. Upon graduation from the USNavy Test Pilot School (1954) was engaged in the Electronics Test Division of the US Naval Air Test Centre. In 1962 graduated from the University of Colorado as B. Sc. in aeronautical engineering. Joined the group of astronauts of the NASA in 1959. Made an orbital flight in the *Mercury* (*MA-7*, also known as the *Aurora-7*) spaceship on May 24, 1962, circling the Earth 3 times in 5 h.

CATALYST. A substance which accelerates chemical reaction without undergoing permanent chemical changes and is consumed only due to entrainment. Used in rocket engineering to decompose some propellant components or monopropellants, such as hydrogen peroxide or hydrazine, and for other purposes. Hydrogen peroxide, for instance, is decomposed by metallic oxides, silver and other substances.

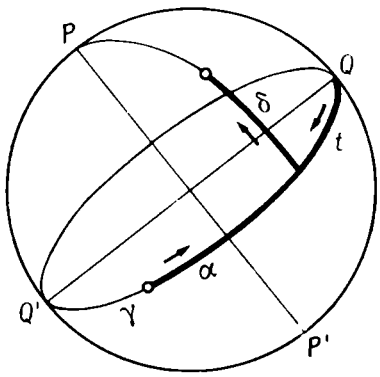
CATALYTIC OXIDATION. A method of mineralization of metabolic by-products based on their decomposition at elevated temperatures with subsequent oxidation of the simpler organic compounds formed, using catalysts (Co, Fe, Ni and their oxides). The use of catalysts makes it possible to considerably lower the oxidation temperature and to avoid the unfavourable effects produced in the mineralized products when exposed to high temperatures (sublimation of potassium and sodium, formation of carbides, generation of molecular nitrogen, etc.). The optimum conditions for catalytic oxidation are a decomposition temperature of 300—500°C and an initial temperature at the catalyst of 200—800°C; 90—99% mineralization can be obtained.

CATAPULT, ground-type. Rack for training pilots and spacemen for shock accelerations. It is also used for physiological studies and evaluation of various types of ejection seats. The g-force during ejection is usually within 20 to 25 g, and the duration is 0.1 to 0.2 s.

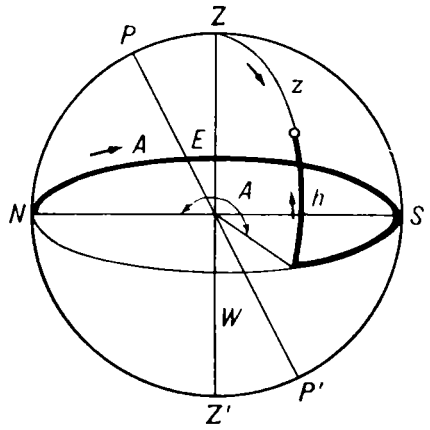
CAVITATION. The formation of liquid discontinuities (cavities, bubbles) filled with vapours. This occurs in areas with low pressure equal to the vapour saturation pressure. When the bubbles enter a zone of increased pressure, this is accompanied by their rapid condensation and microhydroshocks which cause the erosion of materials and other undesirable effects. Cavitation may take place in pumps, valves, hydraulic return lines and actuators of rocket engines. Difference must be made between a developed cavitation that brings about the pump failure and a local cavitation that does not noticeably effect the pump characteristics.

CELESTIAL AXIS. The straight line passing through the CELESTIAL SPHERE and parallel to the Earth's axis of rotation. The celestial axis intersects the celestial sphere at the celestial poles.

CELESTIAL COORDINATES. Numbers used to define the positions of celestial bodies and auxiliary points on the CELESTIAL SPHERE. The following systems are in use. The horizontal system, in which the fundamental



Equatorial system of celestial coordinates.



Horizontal system of celestial coordinates.

circle is the true horizon $SWNE$, the pole is the zenith Z of the point of observation; the coordinates are: ZENITH DISTANCE z or ALTITUDE h and AZIMUTH A. The equatorial systems (1st and 2nd), in which the fundamental circle is the celestial equator $Q\gamma Q'$, the pole is the celestial pole P; the 1st coordinate is DECLINATION δ; the 2nd coordinate in the 1st equatorial system of celestial coordinates is the HOUR ANGLE t; in the 2nd system, the RIGHT ASCENSION α. The ecliptic system, in which the fundamental circle is the ecliptic, the pole is the pole of the ecliptic; the coordinates are: the astronomical latitude β (0° to 90° North of the ecliptic and 0° to −90° South of the ecliptic) and the astronomical longitude λ reckoned along the ecliptic from vernal equinox in the direction of the apparent annual motion

of the Sun (from 0° to 360°). The galactic system, in which the fundamental circle is the plane of symmetry of the Milky Way seen from the Earth; coordinates: galactic latitude and galactic longitude.

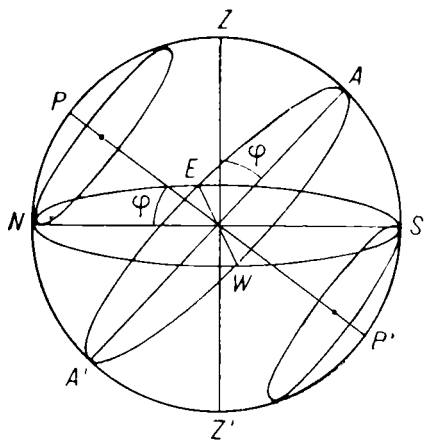
CELESTIAL EQUATOR. The great circle of the CELESTIAL SPHERE whose plane is perpendicular to the axis of Earth's rotation. The celestial equator divides the celestial sphere into Northern and Southern Hemispheres.

CELESTIAL MECHANICS. The branch of astronomy which treats the translational, rotational and deformational motions of bodies under the influence of attractive forces, the resistance of the medium, light pressure, etc. It also treats the motion of artificial celestial bodies on unpowered phases of flight paths. Celestial mechanics studies the following problems: (1) translational motion of the principal planets, which may be regarded as material particles mutually attracted according to the law of universal gravitation; the rapid development of astronautics requires theoretical knowledge of ever higher accuracy, which has stimulated fundamental studies (carried out mainly in the USSR and the USA) aimed at redefining the motions of the principal planets; (2) translational motions of minor planets; (3) motions of satellites of planets; (4) the stability of the solar system; (5) the motion of the Moon; (6) motions of COMETS. Studies of the motions of artificial Earth and Moon satellites and space probes will continue to occupy a prominent place; these problems are similar to those of the motion of natural satellites, however, they require the elaboration of new and more refined methods; the construction of exact theories of motion of these objects is directly related to the solution of other problems of celestial mechanics, such as determining the shapes of the Earth and Moon. Studies of the rotary motions of celestial bodies have been confined to the Earth and artificial Earth satellites; a problem now coming to the fore is that of the rotation of the Moon.

CELESTIAL MERIDIAN. The great circle on the CELESTIAL SPHERE passing through the North and South points, the observer's zenith, nadir and the CELESTIAL POLES. The celestial meridian plane is parallel to that of the Earth meridian passing through the observation points on Earth.

CELESTIAL POLES (North and South). The two points in the Northern and Southern Hemispheres of the CELESTIAL SPHERE at which it is intersected by the celestial axis.

CELESTIAL SPHERE. The imaginary sphere of arbitrary radius on which the celestial bodies are located as seen from an observation post on the Earth's surface (topocentric celestial sphere) or as would be seen from the centre of the Earth (geocentric celestial sphere). Systems of CELESTIAL COORDINATES are introduced for determining the positions of celes-



Celestial sphere.

tial bodies on the celestial sphere. The Figure illustrates the celestial sphere where Z is the ZENITH, Z', the NADIR, $SWNE$, the true HORIZON (and the points are the points of South, West, North and East, respectively); PP' is the CELESTIAL AXIS (P and P' are the North and South CELESTIAL POLES), $AWA'E$ is the CELESTIAL EQUATOR. The celestial axis makes, with the plane of the true horizon, an angle φ equal to the geographic latitude of the site of observation. The line NS, which connects the points of North and South, is called the noon line. The ECLIPTIC makes an angle $\varepsilon = 23°27'$ with the CELESTIAL EQUATOR and intersects with it at the points of vernal and autumnal equinox. In solving problems involving rotation of the Earth, the celestial sphere is considered to be in rotation from East to West with a period equal to one sidereal day.

CENTAUR. A rocket stage of the American *Atlas-Centaur* launch vehicle. It weighs about 17 t and has 2 liquid-propellant engines with a total thrust of about 13.6 t. *Centaur* was the first rocket to use LOX and liquid hydrogen as propellant.

CENTRAL PRE-LAUNCH CONSOLE. Designed for checking the operation of the automatic and remote control systems of pre-launch preparation, this console is located at the launch control centre. It is to this console that the information on execution of the pre-launch operations is fed. The signals and commands emerging from the central pre-launch console are supplied in a reduced form to the launch console. The pre-launch consoles find application in the ground support equipment of giant space vehicles.

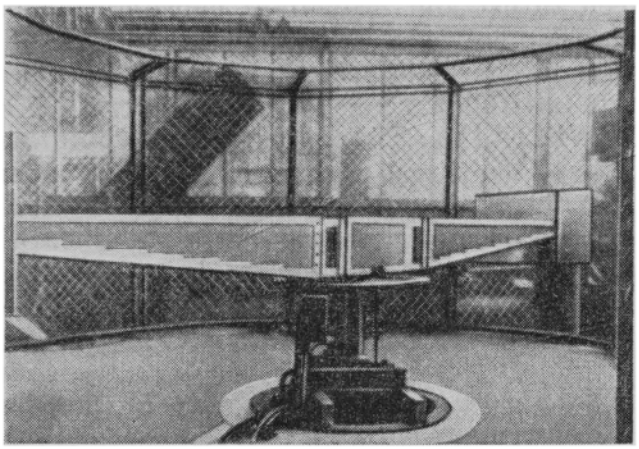
CENTRIFUGAL PUMP. A blade-type machine in which the mechanical energy of the drive is transformed into the potential and kinetic energy of a fluid by means of a revolving impeller fitted with blades. The fluid flows between the blades from the impeller axis to its periphery. The centrifugal pump is the main type of pumps of rocket engines used for feeding liquid propellants or the working fluid; it can be single- or multi-stage, and with input of the fluid from one or both sides of the impeller.

CENTRIFUGE. A ground installation used in selection and training of spacemen for simulation of long-term accelerations. The centrifuge is a complex structure 15 m and over in radius; its motors have a power of several thou. kW. This makes it possible to create a centripetal acceleration of 40 g and over with rate of acceleration build-up of up to 5—15 m/s^3.

The position of the man being tested in the centrifuge cabin determines whether the acceleration effects are in the seat-to-head, head-to-seat, chest-to-back, back-to-chest, lateral or any other intermediate direction. There are centrifuges equipped with a cabin-rotating mechanism that can change the direction in which acceleration acts, without stopping the centrifuge, and thus bring test conditions closer to the real flight conditions. The centrifuge cabin can also be used as a pressure chamber if it is connected through a collector and a tube system with a vacuum pump. The vestibular apparatus is studied and trained using angular acceleration which is an adequate stimulant for the semicircular canals. Hence, small-radius installations and those with axis of rotation passing through the head of the test man are used.

An objective evaluation of the test man state is a matter of difficulty.

Electrophysiological methods are used for this purpose most frequently. Biopotentials pass from the test person through electrodes into pre-amplifiers mounted either directly in the centrifuge cabin or on the rotation frame. A special collector is installed strictly along the rotation axis. From the pre-amplifiers the biopotentials pass through the collector into the control room, where they are recorded by electronic instruments. In addition to the biopotentials, instruments analyze other physiological functions, such as arterial



Centrifuge

pressure, volumetric values of external respiration, CO_2 and O_2 concentration in air inhaled and exhaled, oxygenogram (oxygen saturation of hemoglobin), etc. The test man is observed by TV; X-ray observations are also made. Space-borne equipment is also tested on centrifuges.

CERNAN, Eugene A. (born 1934, Chicago, Ill). US astronaut, USNavy lieutenant-commander. Upon graduation in 1956 from Purdue University, served at the Naval Air Station, Miramar, Cal. Later graduated from the USNavy School in Monterey, Cal. Joined the NASA group of astronauts in 1963. Made an orbital flight in *Gemini-9* as co-pilot to T. Stafford on June 3, 1966; circled the Earth 44 times in 72 h covering ~1,900,000 km. During this flight he made a 2-hour space walk. Together with T. Stafford and J. Young he made a space flight in *Apollo-10* on May 18—26, 1969, and went into selenocentric orbit on May 21. He and T. Stafford spent 8 h in the *Lunar Excursion Module*, debugging its manoeuvring system in circumlunar space; they descended to 15 km above lunar surface. After docking with the spaceship, they returned to the Earth. Cernan was in orbit round the Moon 61 h 40 min.

CHAFFEE, Roger Bruce (born 1935, Grand Rapids, Mich., died 1967, Cape Kennedy). US astronaut, lieutenant-commander in the USNavy. Graduated from Purdue University, where he received the degree of B. Sc. in aeronautical engineering. In 1957 became a USNavy officer and served at an Air Force Base in Florida. Joined the group of astronauts of the NASA in 1963. Chaffee was to make an orbital flight in an *Apollo* spaceship together

with V. GRISSOM and E. WHITE. The three astronauts perished when the capsule of the spaceship caught fire on ground.

Change of orbital plane

CHANGE OF ORBITAL PLANE OF EARTH SATELLITE. See MANOEUVRE.

CHANNEL OF PITCH, yaw, roll. See PITCH, YAW, ROLL.

CHARACTERISTICS OF ROCKET ENGINE. The main parameters and properties of a rocket engine: thrust, specific impulse, gas pressure in the combustion chamber, weight, size, reliability, etc., as well as the dependence between these main parameters (e.g., the throttle characteristic, i.e., the dependence between thrust and propellant consumption or pressure in the combustion chamber) or between these parameters and parameters of environment (e.g., altitude characteristic, i.e., dependence between the engine thrust and its flight altitude).

CHARACTERISTIC VELOCITY. The velocity that would have been acquired by the spacecraft due to the thrust of the rocket engine under ideal conditions of operation, i.e., in the absence of other forces (attraction of planets, aerodynamic drag, etc.) and on moving along a straight line. Slight errors due to the scatter of the rocket engine parameters being taken into account, the characteristic velocity determines the amount of the WORKING FLUID (propellant) consumed by the engine, and, therefore, reference is often made to the losses of characteristic velocity rather than the consumption of propellant (e.g., the loss in characteristic velocity on landing the spacecraft, spacecraft manoeuvres with a minimum loss of characteristic velocity, etc.).

CHARGE of solid propellant. A propellant grain of a definite shape loaded into the combustion chamber of a solid-propellant engine. Prepared by extrusion (wafers) or by casting in cases. The surface of the charge not designated for burning is inhibited, i.e., covered with an inert material. Charges are classified as end-burning, side-burning and unrestricted-burning charges. Sides of the charges may be cylindrical or of a special shape. The geometrical shape of the burning surface determines the thrust vs time characteristics of the solid-propellant engine on the phase of quasi-steady burning. The charges can be bonded to the walls of the combustion chamber or loaded by inserting them freely into the combustion chamber with the end resting on the grid (grate) bar of the nozzle. When burning, the charges undergo considerable mechanical stress, especially when they are bonded to the walls of the combustion chamber. Thermal stresses originate in storage of solid-propellant engines, as well as in flight due to aerodynamic heating of the combustion chambers with case-bonded charge. As a rule, brittle and hard propellants are used for preparing uninhibited freely loaded charges. Case-bonded charges should be made from elastic propellants.

CHEMICAL IGNITION. Ignition of the main propellant in a liquid-propellant engine if the main propellant is hypergolic (self-igniting), or use is made of a hypergolic auxiliary propellant for starting combustion. In particular, it is possible to use one component of the starting propellant, forming a hypergolic pair with one of the components of the main propellant. Chemical ignition of liquid-propellant engines was first suggested at the Gas Dynamics Laboratory in 1931 for *OPM-3* engine, and was used in the engines *OPM-50*, *OPM-52* and others in 1933. Subsequently, it has been widely applied in rocketry.

CHEMICAL PROPELLANT. A substance or combination of substances capable of releasing, as a result of the chemical reactions of decomposition or oxidation, heat energy carried by the reaction products, that are used in rocket engines as the working fluid. Chemical propellants are classified as: LIQUID PROPELLANTS; SOLID PROPELLANT; hybrid propellants; GELLED and THIXOTROPIC PROPELLANTS are under test. It is possible to use solids as components of liquid propellants, e.g., SUSPENSIONS of metals and metalloids, mixtures of solid and liquid hydrogen, as well as fluidization of the solid component of propellants (see QUASILIQUID PROPELLANT). Chemical propellants include hypothetical MONATOMIC and METASTABLE PROPELLANTS.

CHEMICAL ROCKET ENGINE. A rocket engine that uses a chemical propellant. The propellant's potential chemical energy is transformed into heat energy in the combustion (decomposition) chamber, then, when the products of the reaction expand in the engine's nozzle, the heat energy transforms into the kinetic energy of the jet efflux. All actually existing rocket engines, except experimental ones of other types, are chemical rocket engines (see Fig. on p. 282).

CHLORELLA. The general name for green unicellular algae used in experimental biological air-recovery units of the LSS in spaceships. Characterized by a high capacity for PHOTOSYNTHESIS. Its chemical composition makes it an almost nutritively complete foodstuff.

CIRCULAR MOTION. The motion of a celestial body on a circular path. Examples of circular motion are some particular cases in the solution of the PROBLEM OF TWO BODIES. Like solutions are also possible in the PROBLEMS OF THREE BODIES and n-bodies, as well as in the problem of a particle motion under the attraction of a body possessing dynamic symmetry about some axis.

CIRCULAR VELOCITY. The velocity required for motion on a circular orbit. If a body's velocity at the initial moment of time is perpendicular to the radius vector, its undisturbed motion is circular.

CLAUSTROPHOBIA. Abnormal dread of being in closed space. The long periods spent by spacemen in sealed cabins and space suits make it necessary to subject all crew candidates to tests for claustrophobia in what are known as ISOLATION CHAMBERS.

CLOCK PARADOX. A corollary of the special theory of relativity according to which among an infinite number of possible inertial (moving at constant velocities) frames of reference it is impossible to chose a preferred one. From this point of view, time in a moving reference system dilates proportionally to

$$(1-v^2/c^2)^{-1/2}$$

where v is the speed of travel, c is the fundamental constant (speed of light). In view of that, the duration of a localized process measured by pre-synchronized clocks moving at different speeds would prove to be different. Therefore, within the framework of this theory it is impossible to determine the absolute duration of any process, while from the view-point of conventional physics it must have a definite value. The clock paradox can be checked experimentally by means of satellites.

Closed biotechnical system

CLOSED BIOTECHNICAL SYSTEM. A biotechnical system of a spaceship without exchange of materials with the environment, but receiving energy from outside and dissipating the same quantity of energy. The closed biotechnical system consists of a number of species of living organisms (including man) whose relations are based on a balanced rate of metabolism. Within the limited space of a sealed cabin this system effects a cyclic reproduction of the materials necessary for man (oxygen, food and water) from biological wastes. When designing a closed biotechnical system, it is necessary to include a minimum number of the biocomplex members, to have a maximum material circulation rates and synchronization; processes should be eliminated if they give rise to materials that drop out of the cycle and are not assimilated by other biocomplex members; the system should be as simple as possible; optimum system self-adjustment that ensures maximum reliability should be provided.

CLOUD OF IONIZED PARTICLES. A cloud formed by the action of sunlight on metallic particles released from the container of a rocket at an altitude of several hundred km. Clouds of ionized particles serve as a short-life PASSIVE RELAY STATION providing omnidirectional diffusion of radio waves for establishing a radio relay line of communication. Irradiation of the cloud by an auxiliary radio transmitter on the ground increases ionization and, consequently, the duration of regular communication from 30 min to 5—8 h.

CLUSTER ROCKET ENGINE. A rocket engine assembly consisting of several propulsion units (engines designed only for the cluster and lacking certain elements), having common ignition systems, mount, etc. The advantages of a cluster rocket engine over single-chamber engines are greater thrust developed by an assembly of low-thrust units (thrust chambers, turbopump unit, etc.) and shorter length.

COAGULATION. Diminution of dispersity, i.e., enlargement of particle sizes of a dispersion system by a change in temperature, concentration of solution, addition of a salt, etc., as well as by centrifugation or treatment by an electric field (electrocoagulation). It can be efficiently employed as one of the methods for pre-processing of sanitation water in a spaceship LSS. If the products of propellant combustion contain condensable compounds, coagulation may occur in the nozzle and reduce the SPECIFIC IMPULSE of the rocket engine.

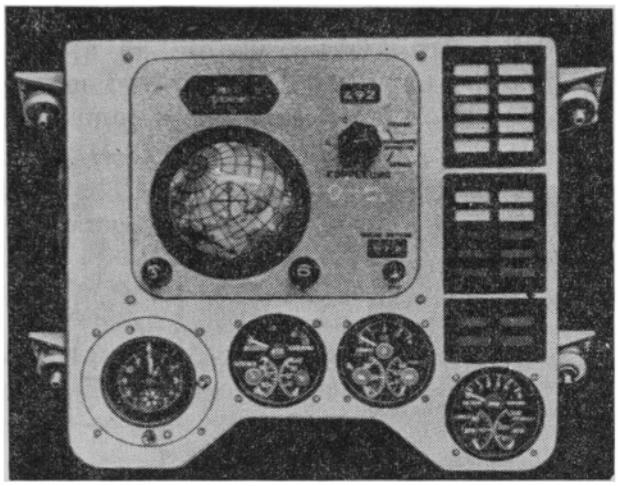
COCKPIT INSTRUMENT PANEL. A board included in the spaceman's cockpit. It mounts the measuring instruments and indicating devices which monitor the state and operation of the spaceship systems. Mounted on it are: pointer instruments, digital indicators, visual display shields, indicating lights and the like. On satellite-spaceships the instrument panel also usually carries a globe rotated by a programmed device to indicate the geographical position of the spaceship at any moment of time.

COLLINS, Michael (born 1930, Rome, Italy). US astronaut, USAF major. Graduated from the US Military Academy. Served as a test pilot at the Edwards Air Force Base. Joined the group of astronauts of the NASA in 1963. Acting as co-pilot, he made an orbital flight on July 18, 1966, together with J. YOUNG in the *Gemini-10* spaceship. In the course of this flight he made two

space walks. On meeting the *Agena-8* target missile in orbit, M. Collins approached it and removed a device used for the study of micrometeorites.

COLLOIDAL GUNPOWDER. See HOMOGENEOUS SOLID PROPELLANT.

COLLOID ROCKET ENGINE. An electrostatic rocket engine, whose jet efflux, besides ions, contains comparatively heavy electrically charged particles (e.g., drops of oil, solid particles, etc.) with a very big mass-to-charge



Instrument panel of *Vostok* spaceship.

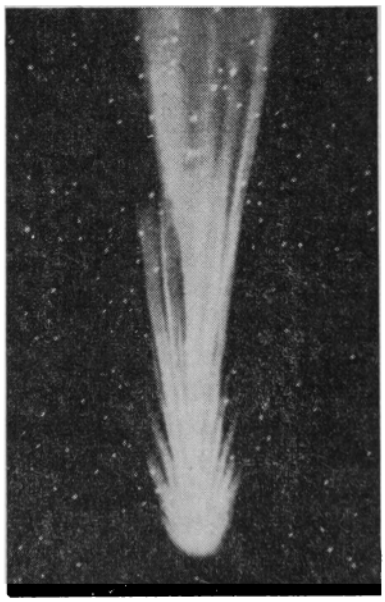
ratio. That is why very high acceleration voltages (up to several million V) are required to produce an acceptable exhaust velocity. The engine is yet in the stage of experimental development.

COMBINED METHODS OF SPACE NAVIGATION. A combination of different means and principles of space navigation (inertial, astronomical and radionavigation). The most widely used are radioinertial and astroinertial combined methods of navigation. A combination of all the three basic principles of navigation may be employed for the solution of complicate problems

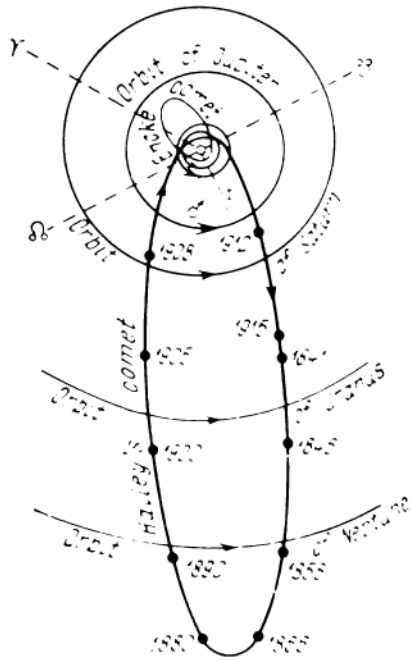
COMBUSTION TEMPERATURE. The mean stagnation temperature of the combustion products at the outer part of the combustion chamber. To facilitate the cooling of the combustion chamber of a liquid-propellant, nuclear and certain electric engines, the layer of gas adjoining the walls usually has a lower temperature, while in the central part of the flow, beyond the layer adjoining the walls (if there is sufficiently good mixing) the stagnation temperature is close to permanent and is the combustion temperature. The estimated combustion temperature is obtained from the thermodynamic analysis of the rocket engine. The actual combustion temperature is close to the theoretical one and amounts to 3500°—3600°K for oxygen—kerosene and oxygen—dimethyl hydrazine propellants, 3100°—3200°K for nitric acid—kerosene and nitric acid—dimethyl hydrazine propellants, 3400°—3500°K for nitrogen tetroxide—dimethyl hydrazine and oxygen—hydrogen propellants, and 4700°—4800°K for fluorine—hydrogen propellants; in solid-propellant engines it is 2200°—3000°K for homogeneous propellants and 1700°—2900°K

for heterogeneous propellants. The combustion temperature depends on the EXCESS-OF-OXIDIZING-ELEMENTS COEFFICIENT of the propellant and reaches the maximum when this ratio approaches 1. With the growth of pressure in the combustion chamber the combustion temperature rises slowly as a result of a lower dissociation (a pressure gain of 50 at changes the combustion temperature by 20—50°). The specific impulse of a rocket engine is proportional to the square root of the value of combustion temperature (the molecular weight of the combustion products being the same).

COMET. A body in the SOLAR SYSTEM visible as a nebular object with a light conglomerate inside known as the core, and moving relative to the stars. The bright comets have visible tails. As a comet approaches the SUN,



Morehouse's comet.



Orbits of Halley's and Encke-Backlund's comets.

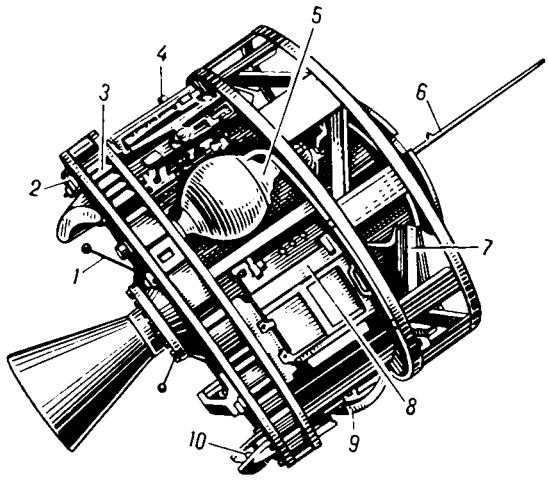
the core becomes heated, and gases and dust are released from it. The latter give rise to the nebulous coma which, together with the core, forms the head of the comet. Light pressure and interaction with the SOLAR WIND carry the gases and dust away from the core and form the tails that point away from the Sun. The cometary mass (10^{14} 10^{20} g) is mainly concentrated in the core. The cores have diameters ranging from 0.5 to 50 km. The head diameter may be from several thousand to 2 million km in cross section, changing in one and the same comet as the distance from the Sun changes; some tails have been observed to extend up to 200 million km from the core. The luminosity of the comet's solid core, consisting of various ices with admixtures of nonvolatile substances is due to reflected sunlight; the gases of the head (carbon, cyanogen, etc.) and of the tail (carbon monoxide, nitrogen and other neutral or ionized molecules) are extremely rarefied and luminesce un-

der the action of in-resonance reradiated sunrays and fluorescence. Nearly 200 known comets move around the Sun in definitely eliptical orbits. Short-period comets approach the Sun every few years, spend their reserve of gases and disintegrate. Most comets have orbits several thousand times the diameter of the planetary system; their periods are millions of years. All comets belong to the solar system. Only rare individual comets acquire hyperbolic orbits and leave the solar system due to outside perturbations. Comets are named in honour of the discoverer or the individual responsible for important research on their movement. Among the periodic comets that will return to perihelion by 1986, five will have conditions suitable for study by launching automatic interplanetary stations. These are Templia's 2 (1967), Encke-Backlund's (1974), D'Arrest's (1976), Kopf's (1983) and Halley's (1986).

Complete-ness of combustion

COMMON TIMING SYSTEM. The aggregate of space centre stations equipped with special clocks (atomic, molecular or quartz type) and intended to supply reference frequencies and timing reference signals to a specified range of consumers. The timing signals transmitted from one centre to a number of consumers allow to synchronize the work of various systems and services of the launch complex and the space centre as a whole, to fix the exact beginning and end of operation of multiple instruments, devices, machines, systems and units during the pre-launch preparation, launching and flight of the launch vehicle.

COMMUNICATIONS SATELLITE. A space communication station that serves for relaying radio signals between ground stations located far beyond line-of-sight. According to the type of repeater employed, communications satellites may have either PASSIVE or ACTIVE RELAY STATION on board and, according to the type of orbit, they may be NON-STATIONARY SATELLITES (*Telstar*, *Relay*, *Echo* and others),



Syncom-2 communication satellite with a repeater on board:

1—collapsible-whip antenna of telemetry and command systems; *2*—jet nozzle of attitude control system; *3*—nickel-cadmium storage battery; *4*—radio receiver; *5*—hydrogen peroxide bottle (propellant for attitude control system); *6*—coaxial slot antenna of communication system; *7*—radio transmitter with travelling-wave tube; *8*—command radio receiver; *9*—nitrogen bottle for attitude control system; *10*—Sun sensor.

with an elliptical synchronous orbit (*Molniya*), or STATIONARY SATELLITES (*Early Bird*). The Fig. shows the design of the *Syncom-2* communications satellite equipped with an active relay station. See also SYSTEM OF RADIO COMMUNICATION VIA MOLNIYA-1 SATELLITE. The *Molniya*-1 and the *Early Bird* satellites were used in 1966 for regular commercial communication.

COMPLETENESS OF COMBUSTION. The value characterizing the degree of propellant conversion into products of complete combustion (e.g., the

Complete-ness-of-pressure coefficient

carbon in the propellant into CO_2, hydrogen into H_2O, etc.). Completeness of combustion determines the fraction of the potential chemical energy of the propellant converted into heat energy in the process of combustion in the rocket engine. Incomplete combustion is caused by: dissociation of the components of combustion products, an excess of one of the propellant components as compared with the stoichiometric composition, an additional consumption of propellant components for internal cooling, unsatisfactory mixing, etc. Often incomplete combustion due to dissociation and to difference from the stoichiometric composition of the propellant is considered separately from other losses. In particular, when determining the COMPLETENESS-OF-PRESSURE COEFFICIENT these losses are not taken into account.

COMPLETENESS-OF-PRESSURE COEFFICIENT. The ratio of the actual specific impulse of pressure to the estimated one (see Thermodynamic analysis of rocket engine), computed for the same values of EXCESS-OF-OXIDIZING-ELEMENTS COEFFICIENT and chamber pressure (i.e., the STAGNATION PRESSURE in the throat section of the nozzle). This coefficient characterizes the efficiency of combustion processes in the thrust chamber; it increases with an increase in the completeness of combustion (is proportional to the square root of the combustion temperature). It is usually equal to 0.96—0.99.

COMPONENT TESTS. Tests of individual systems, assemblies and units of the space vehicle and ground support equipment, aimed at ensuring correct operation of the components and performed at maintenance area and on the launching site with the use of checkout instruments. The component tests constitute the first stage of schedule maintenance tests and pre-launch checkout.

COMPOSITE ROCKET ENGINE. A rocket engine which is a combination of engines of different types, e.g., rocket-ramjet, turborocket, nuclear-electric and other engines. Some combination engines may be used for space flight.

COMPRESSED GASES. Gases used as the working fluid in the pneumatic automation systems of ground equipment and launch vehicles as well as for pressure-feeding of propellants from ground reservoirs into the launch vehicle tanks and for pressurization of the ground reservoirs and the launch vehicle tanks. Various rocket systems utilize compressed air, nitrogen, or helium. The simplest way is to obtain compressed air by using conventional compressor plants, though sometimes the use of air proves to be impossible since oxygen of the air is absorbed by the propellants or, in the case of CRYOGENIC PROPELLANT tank pressurization, the air condenses which leads to pressure oscillations in pressurized vessels and to the propellant contamination. In such cases an inert gas is used, e.g., nitrogen with a boiling point of —196°C. However, if liquid HYDROGEN (boiling point —253°C) is used as fuel, nitrogen cannot be used for pressurization and pressure-feeding of the fuel since nitrogen condenses on the surface of hydrogen, which also occurs when nitrogen is used for pressurizing a tank with supercooled oxygen. In this case gaseous helium (boiling at —269°C) proves effective.

COMPRESSOR PLANT. A portable or stationary installation, a complex of machines, units, measuring instruments and means of control for compressing air, nitrogen or helium. The service pressures of space center compressor

plants reach 400 at. Air desiccating units ensure a moisture content corresponding to a dew point not higher than —55°C.

COMPUTER BLOCKS. See CONVERTING DEVICES.

CONDENSER of LSS. A device for condensation of water vapours contained in the gas mixture, its cooling and separation of the liquid phase from the gaseous. Condensers are used in spaceship LSS and space backpacks to remove moisture from the air, water from the vapour-gas mixture produced in the systems of electrolysis of water, salt solutions and melts, catalytic hydrogenation of carbon dioxide, etc. In space flight conditions the methods used on earth for water vapour condensation and liquid—gas separation, excepting the capillary condensation method, cannot be used because of weightlessness. Therefore, use is made of expanded tubular or other surfaces cooled on the inside by a coolant with water vapour condensation temperature. The liquid thus formed (condensate) is drained by porous hydrophilic materials adjoining the cooling surface. The condensate is then conveyed to other units by a capillary gradient or a pump, or to a storage container by periodically squeezing it out of the hydrophilic porous materials.

CONGREVE, Sir William (1772—1828). Colonel, British artillerist, inventor of various types of war rockets. Congreve drew on the experience of the Hindoos in the use of rockets against the British in India, in particular, in the battles at Seringapatam in 1792 and 1799. In 1801 Congreve began to work on improvement of rockets by increasing their range. He considered the absence of recoil one of the chief advantages of rocket artillery and he successfully demonstrated the use of his rockets in the British naval attack on Boulogne in 1806 where they were very effectual. His incendiary rockets were employed by the British with excellent results in the sieges of Copenhagen in 1807 and Danzig in 1813, and the battle of Leipzig. The last of the Congreve rockets weighed up to 20 kg and had a range of 2700 m; as their name indicates, the rockets were incendiary, high-explosive, shrapnel and illuminating. After 1813, Congreve introduced rockets with a central guide tail to improve the firing pattern.

CONIC SECTION. A curve of the 2nd order obtained at the intersection of a cone by a plane that does not pass through the apex of the cone. A circle, ELLIPSE, PARABOLA and HYPERBOLA are examples of such sections.

CONRAD, Charles (born 1930, Philadelphia). American astronaut, lieutenant-commander in the USNavy. Upon graduation from Princeton University in 1953 served with the Navy. Graduated from the USNavy Test Pilot School in Maryland in 1961 and worked there as a test pilot, instructor and engineer. Later served at the Naval Air Station in Miramar. Joined the group of astronauts of NASA in 1962. He made his 1st orbital flight together with G. Cooper on August 21—29, 1965, as co-pilot of *Gemini-5*. Made his 2nd flight in space (with R. GORDON) as the command pilot of *Gemini-11*

launched into orbit on September 12, 1966; this spaceship circled the Earth 44 times in 71 h and covered a distance of ~1.9 million km. In the course of this flight, the spacecraft docked with an *Agena* target missile and artificial gravity was provided in a spacecraft for the first time.

Controlled re-entry

CONTROLLED RE-ENTRY. Atmospheric descent at which the magnitude and direction of aerodynamic forces acting on the re-entry body are controlled within certain limits automatically or by the crew. This permits to reduce the landing area and makes it easier to keep the deceleration and aerodynamic heating within permissible limits at high initial speed (see RE-ENTRY). The main methods of controlling re-entry are as follows: variation in the direction of the LIFT FORCE (by controlling the roll angle) and its value (by setting the ANGLE OF ATTACK) and changing of the drag.

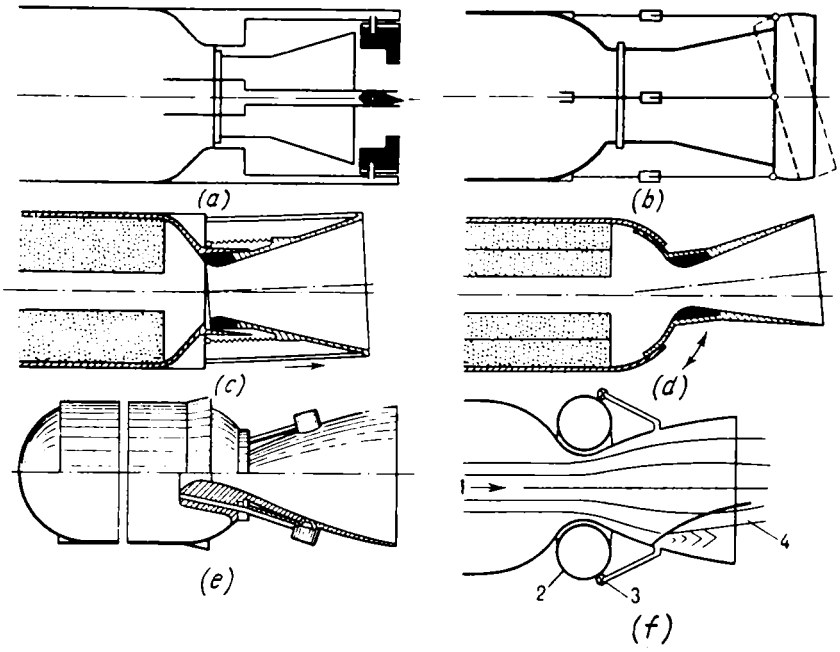
CONTROLLING MOMENT. A moment that serves to establish the specified angular attitude of a spacecraft when orientation or angular stabilization of the latter is performed. Various methods are employed for producing a controlling moment (see VERNIER ENGINE, REACTION ENGINES, GAS VANES, ATTITUDE CONTROL MOTOR, INERTIAL ACTUATORS, PASSIVE SYSTEM OF ORIENTATION). The controlling moment is to be sufficient for opposing expected DISTURBING MOMENTS.

CONTROL OF LIQUID-PROPELLANT ENGINE. Automatic maintaining or programmed changing the parameters of the working process of a liquid-propellant engine to ensure the assigned values of thrust and MIXTURE RATIO, the stable operation of the liquid-propellant engine, as well as control of the transient processes (starting, cutdown, etc.). The control of a liquid-propellant engine is effected by a system inside the engine, or outside it (a rocket system), or by both. Thrust (throttling, afterburning) is usually controlled by changing the propellant flow rate, the nozzle throat area remaining permanent (gas pressure in the combustion chamber being variable). During the nominal mode of operation of a liquid-propellant engine the mixture ratio is maintained such as to ensure the maximum SPECIFIC IMPULSE. Otherwise, apart from the drop in specific impulse due to the premature burnout of one of the propellant components, residuals are left of the other component leading to a shorter burning time and the resulting reduction of the rocket burnout velocity. A limited control of a liquid-propellant engine is only possible. Control within a wide range requires special measures to be adopted in order to eliminate the engine overheating and instability of the combustion process.

CONTROL OF SOLID-PROPELLANT ENGINE. Changing the operation of a solid-propellant rocket engine to ensure the assigned value of thrust. This is achieved usually by changing the combustion surface of the propellant charge by imparting in advance a certain geometrical form to it. Provision for two stages of thrust which is required in some instances is ensured either by the geometrical form of the charge or by the use of a composite propellant charge. It is theoretically possible to control a solid-propellant engine by changing the nozzle throat area of using factors influencing the rate of charge combustion.

CONTROL OF THRUST VECTOR. Positive changing of direction of the rocket engine thrust vector to ensure the pitch, yaw and roll control of the

rocket. This is effected by turning (e.g., gimballing) the rocket engine thrust chamber, or by means of a swivelling main nozzle, jet vanes, turning flaps on the periphery of stream, unsymmetrical injection of a liquid or blowing of



Some possible means for controlling thrust vector of rocket engine: (*a*) gas vanes; (*b*) swivelling ring on nozzle outlet; (*c*) elastically joined tilting nozzle; (*d*) gimballed nozzle; (*e*) jet efflux deflection by gases introduced from combustion chamber into nozzle; (*f*) jet efflux deflection by liquid injection into nozzle.

1—direction of gas flow; *2*—liquid container; *3*—valve; *4*—diverted gas flow.

a gas into the nozzle divergent section, changing thrust or cutting off several engines in a multiengine powerplant, or by using auxiliary fixed or swivelling nozzles, gimballed control engines, etc.

CONVERTING DEVICES (converting and amplifying devices, computer units, logical units) of control system. Devices used as an intermediate link between the SENSING ELEMENTS and the ACTUATORS of a system of spacecraft control. The main functions of the converting devices are: amplification of the sensing element signals and conversion of the latter into a form suitable for actuating the actuators combination of the signals of several sensing elements and performance of logical and mathematical operations with the signals. Spaceborne electronic computers may be included in cases when complex operations are to be performed and a high accuracy of control is required.

COOLANT. A substance used to cool thrust chambers, gas generators and other units of rocket engines. In liquid-propellant engines, the role of the coolant is mostly played by one of the propellant components, e.g., kerosene, unsymmetrical dimethyl hydrazine, hydrogen peroxide, hydrogen,

ammonia, etc. The coolant should possess thermal stability in a sufficient range of temperatures, high heat capacity, high boiling temperature, etc. Auxiliary substances, such as water, are used sometimes, e.g., during laboratory tests (see COOLING OF ROCKET ENGINE). In nuclear rocket engines, the reactor and nozzle are cooled by the working fluid (hydrogen).

COOLING OF PROPELLANT LINES. Forced cooldown of the propellant-feed lines, hydraulic accessories and pump casings of the propellant-loading system, as well as the propellant tanks of the launch vehicle, to a temperature near to the b.p. of low-boiling and cryogenic propellant employed. This is done in order to avoid the danger of propellant boiling during loading, which may be accompanied by a sharp pressure rise in the propellant lines and the launch vehicle tanks. Sudden cooling of the propellant pipelines and tanks causes thermal deformations of the latter, that, in turn, are liable to impair the tightness of the system; besides, a gas-lock appears in the pump, which prevents its normal operation. Prior to fuelling, a small amount of the cryogenic propellant is supplied at low pressure into the propellant lines. The propellant evaporates in the lines and the gas, first superheated but gradually, as cooling progresses, acquiring a lower temperature, flows through the launch vehicle tanks and is eventually expelled into the atmosphere through the drain-and-safety valves of the tanks. The process of cooling is discontinued and the loading of the tanks with the propellant is initiated as soon as the propellant manifolds and tanks acquire a temperature nearly equal to the b.p. of the cryogenic propellant. Propellant-feed lines are also cooled down prior to in-flight re-starting a rocket engine burning a cryogenic propellant.

COOLING OF ROCKET ENGINE. The cooling of the walls of the thrust chamber, gas generator, turbine vanes and other elements of a rocket engine by COOLANTS or by other means. Because of the very high HEATING RATES at the walls of the thrust chamber and due to the complexity of creating a forced circulation of the coolant in the rocket engine's components (turbines, bearings, etc.), cooling is one of the biggest problems encountered in designing rocket engines. The cooling of surfaces by means of a coolant may be external and internal. In the case of external cooling, the coolant is forced through the jacket of the thrust chamber, gas generator or another element, and cools the inner surface which is in contact with combustion products (working fluid) without a mass exchange with the latter. In this case cooling is effected by a propellant component before it enters the combustion (heating, etc.) zone or by an interim, auxiliary heat carrier that is further cooled by one of the propellant components. This is called the regenerative cooling. When regenerative cooling is provided, the thermal energy taken off the walls is returned to the engine's combustion chamber (is regenerated), and therefore there are no thrust losses due to cooling. The widely used regenerative cooling of rocket engines was first suggested by K. E. Tsiolkovsky.

If the cooling of a rocket engine is effected by an auxiliary coolant and the heat absorbed by it is not returned to the thrust chamber or gas generator, such cooling is called independent. It is used on experimental and model rocket engines during static firings.

If the external cooling proves to be insufficient, a type of internal cooling is used in which the layer near the walls is enriched by one of the propellant components (or by the working fluid) through specially located INJECTORS so as to lower its temperature. Alternatively, FILM or TRANSPIRATION COOLING may also be used. The cooling of rocket engines in some cases is effected without a coolant. The rocket engines that operate for short periods only and do not generate high thermal stresses, are cooled by directing some of the heat to melting or sublimating the structural material or a layer of a special substance covering the wall (see ABLATION COOLING), or by accumulating heat in the wall. In the latter case the walls are made thick and of materials with high thermal conductivity, melting point and heat capacity. The cooling of rocket engines or of their individual components, in the event of low heating rates, can be effected by radiating heat into space (see RADIATION COOLING). A protective coating of refractory materials of low thermal conductivity is sometimes laid on the gas-contacting walls of the rocket engine to lessen the effect of hot gases.

COOPER, Leroy Gordon, Jr. (born 1927, Shawnee, Okla.). American astronaut, USAF lieutenant-colonel. Upon graduating from the University of Hawaii in 1949 he became a USAF officer. Graduated from the Air Force Institute of Technology in 1956 and from the Air Force Experimental Flight Test School at Edwards Air Force Base. Was engaged at the Edwards Air Force Base as test pilot and engineer. Was selected for the group of astronauts of the NASA in 1959. Made his 1st orbital flight in the *Mercury* (*Faith 7*) spaceship on May 15—16, 1963, circling the Earth 22 times in 34 h 20 min and covering a distance of 870 thou km. He made his 2nd flight into space as commander of the *Gemini-5* spaceship (together with Ch. CONRAD). The spaceship was launched on August 21, 1965, and during its 191-hour flight in space (August 21—29) orbited the Earth 120 times, covering a distance of about 5.3 million km.

CORDITE. See HOMOGENEOUS SOLID PROPELLANT.

CORRECTING NUTRIENT SOLUTION. A solution of mineral salts or mineralized wastes (from storage), intended for maintaining constant concentration of biogenic elements in a nutrient medium during long periods of cultivation of lower AUTOTROPHS in a spaceship LSS. The solution should compensate for the portion of biogenic elements consumed by autotrophs of the LSS. The composition of the solution is determined by the requirements of the autotrophs, the conditions and cultivation regimes.

CORRECTION MANOEUVRE. A change in orbit of a spacecraft in motion. It is executed by thrust pulses of appropriate magnitude and direction on certain portions of the orbit.

CORRECTION OF NUTRIENT SOLUTION. Operations that bring the nutrient solution for plants in the LSS to the accepted standard by removing excess amounts of elements and compounds (sodium chloride, organic substances, metabolites) or by dissolving necessary mineral salts of micro- and macroelements. Mineral salts and mineralized metabolic by-products (ash, urinary mixtures) are used for corrections.

CORRECTION OF ORBIT of Earth satellites. A slight MANOEUVER of an Earth satellite executed for keeping some parameters of its orbit within

required limits. For example, the period of revolution of communications satellites is corrected from time to time so that it always equals the star day or an integral part of the day, thus synchronizing the orbiting of the satellite and the diurnal rotation of the Earth and keeping the satellite on a fixed route with respect to ground stations of the system of radio communication. Correction of the period of revolution is also necessary when setting up STATIONARY EARTH SATELLITES.

COSMIC DUST. The minute particles of solid cosmic matter created by the break-up and disintegration of asteroids and comets, and also by the ejection of tiny particles of the surface layers of the Moon and planetary satellites when large meteorites strike on them. Fallout of numerous cosmic dust clouds has been registered on the surface of the Earth; the total weight of the annual fallout, according to various authors, is between 10^4 and 10^6 t. The dust trains of comets include particles of cosmic dust with a diameter of the order of 10^{-5} cm and a mass of 10^{-13} g. Cosmic dust particles of this size can be registered by instruments of modern spacecraft, but even these are not considered to be the limit of disintegration of solid cosmic matter. The long-term effect of cosmic dust on spacecraft results in what is known as meteoric erosion that in a year destroys a layer of material 10^{-6} to 10^{-4} cm thick.

COSMIC NOISE. Radio-frequency radiation coming from outer space and giving rise to irregularly varying currents in the input circuits of radio receivers. This radiation is generated by distributed and point sources and is manifested within the 10- to 0.3-m band of radio wave-lengths. The intensity of this radiation decreases with shortening of wave-lengths. The most intensive point source of this noise is the Sun. Powerful sources of cosmic noise exist in the Cassiopeia and the Cygnus constellations.

COSMOGONY. Study of the origin and evolution of the SOLAR SYSTEM, stars and their systems (GALAXIES and star clusters), nebula. All the cosmogonic conclusions, theories and hypotheses are deduced from numerous observations of celestial bodies carried out with the aid of all kinds of instrumentation and other equipment including spacecraft.

Of wide circulation is the hypothesis according to which the planetary system is considered to have originated from a gas-dust protoplanetary cloud which some time ago encircled the Sun and extended as far as to the boundaries of the system while the Sun itself took its origin from the rotating and compressing nebula, the protoplanetary cloud separating from it at the concluding state. The separation started under the effect of the centrifugal force and later the separation and distribution of the matter over the entire space of the planetary system was under a considerable influence of its interaction with the magnetic field of the Sun. The planets originated as if in two stages. During the 1st stage which seems to have lasted less than 1 million years, a number of bodies measuring hundreds of km formed of the dust component of the protoplanetary cloud; during the 2nd stage which lasted a few hundred million years, the planets accumulated from a swarm of these "intermediate" bodies and fragments formed during collisions, the largest of them being Jupiter and Saturn. The motion of "intermediate" bodies over the elongated orbits which averaged during accumulation, finally resulted

in circular motions of the planets. Non-elastic collisions of particles in the outskirts of the growing planets led to that some part of particles passed over to the orbits round the planets and accumulated into planet satellites. The Moon appears to have accumulated from the near-Earth swarm at a distance of about 10 Earth radii and later moved off to where it is now due to the tidal interaction with the Earth. Proceeding from the study of radioactive elements and decay products found in the meteorites and the Earth matter, the age of the solar system is estimated to be 4000—5000 million years.

Stars may form owing to the condensation of diffusomatter (gaseous and dust nebulae and inter-stellar medium). The latter is, in turn, replenished by the matter emission from the stars which proceeds either in a continuous way or in the form of eruptions taking place as flares of "nova" or "supernova" stars. The formation of stars in our own Galaxy has lasted for about 10^{10} years and is still going on. The development of cosmogony of galaxies is only in its infancy, it is busy now with the classification of galaxies and their clusters, study of non-stable phenomena in galaxies. The galaxy nuclei have been found to be an important factor in the evolution of galaxies.

COSMOLOGY. The branch of astronomy that treats the general laws governing the structure of the Universe. Cosmology and COSMOGONY are essential for a correct materialistic world outlook.

COSMONAUT. A person who has undergone special medical, biological (see SELECTION OF SPACEMEN), and technical training and taken part in a space flight as pilot or crew member.

COSMONAUTICS. Space travel, all fields of science and technology involved in exploration of space and extraterrestrial bodies with the aid of all types of spacecraft (rockets, man-made satellites, probes, space stations, etc.), either guided from the Earth or manned. Cosmonautics involves aspects both of theory of space flight, e.g., calculation of trajectories, and of technology, e.g., design and manufacture of spacecraft, powerplants, control systems, launch facilities, communication and information transmission systems, research equipment; it also involves medical and biological investigations, etc. October 4, 1957, the date when the first man-made Earth satellite was launched in the USSR, is regarded as the beginning of the space age.

The idea of building vehicles capable of overcoming terrestrial gravity and of travelling in space was first treated scientifically in late 19th century by the Russian scientist K. E. TSIOLKOVSKY. His paper *Issledovaniye mirovykh prostranstv reaktivnymi priborami* (*Exploration of cosmic space by reaction apparatuses*, English title *Rockets into Cosmic Space*), published in 1903, not only evolved the theory of rocket flight with due account for the change in mass during flight, but also proved the technical possibility of space travel. Tsiolkovsky formulated and analyzed a number of problems that with subsequent studies formed the foundation of modern cosmonautics. This field of knowledge owes its existance primarily to Tsiolkovsky although some aspects of space flight have been studied by others. The Russian scientist I. V. MESHCHERSKY, in particular, laid the groundwork for the solution of many theoretical problems in cosmonautics and celestial mechanics in his fundamental work *Dinamika tochki peremennoi massy* (*Dynamics of a Particle of Variable Mass*, 1897).

Tsiolkovsky's ideas caught this imagination of many Soviet scientists and engineers. In early 1921 N. I. TIKHOMIROV established the first Soviet rocket research and development laboratory in Moscow. Upon transfer to Leningrad in 1927, the laboratory was renamed the GAS DYNAMICS LABORATORY (GDL). The GDL inaugurated flight testing of rockets burning granular smokeless powder (1928), tested the first electric rocket engine and liquid-propellant engines in 1929 and 1931, respectively. The GROUP FOR STUDY OF REACTIVE MOTION (GIRD) with affiliated production facilities was set up under the supervision of S. P. KOROLEV in Moscow, in 1932; the GIRD launched the first Soviet liquid rockets in 1933. At the end of 1933 the GDL and GIRD were merged into the ROCKET RESEARCH INSTITUTE (RNII). The GDL, GIRD and RNII laid the foundations of the development of rocketry in the USSR.

Among the first foreign scientists to take interest in jet propulsion, somewhat later than in the USSR, were R. ESNAULT-PELTERIE (France, 1912), R. GODDARD (USA, 1919) and H. OBERTH (Germany, 1923). The 1920's were signaled by the formation of space flight societies in the USSR (1924), Austria (1926), Germany (1927), Great Britain and the USA (1930), whose object was the development and propagation of the ideas of space travel.

R. Goddard pioneered American experiments with liquid-propellant engines in 1923, launching the first liquid rockets three years later. Static tests of such engines were first conducted in Germany by H. Oberth in 1929 and flight tests were carried out by I. Winkler in 1931. In 1932 Germany started developing war missiles. A missile testing ground was established at Peenemünde in 1937 where the *V-2*, a powerful weapon by standards then current, was developed under W. von BRAUN and first tested in flight in 1942. Although the extensive use of the *V-2* at the close of World War II failed to alter the course of the war, it led many nations to speed up their own rocket programmes.

A new development after the war was to use rockets for peaceful purposes, such as atmospheric probes. Although geophysical rockets undoubtedly served a valuable practical purpose, they allowed only a very limited scope of experiments, a shortcoming caused primarily by the short duration and low altitudes of the rocket's flight. There were many scientific and engineering problems requiring solution on a radically new basis that would match the higher level of contemporary technological concepts and the possibilities of their realization, and adequately meet the new challenges of science and production.

Scientific and technological advances are immeasurably increased in scope and variety with the emergence of artificial satellites, automatic interplanetary stations and manned spaceships. They require, however, the solution of a host of problems in theory, science and technology, including primarily the creation of powerful launch vehicles, space centers, as well as artificial Earth satellites, spaceships, automatic interplanetary stations, and space probes carrying suitable scientific equipment and designed to cope with the conditions of space; spacemen training, etc. Adequate solution of this complex of problems requires tremendous endeavour and outlay, wide-range coordination of research programmes, and a good deal of scientific daring. Although

the need to develop and launch satellites was occasioned by the very progress of science and engineering, one of the stimuli to speeding up satellite development was the 1957—58 International Geophysical Year. The IGY, a sort of international review of scientific and technological progress, was highlighted by the USSR's launching of the world's first man-made satellite on October 4, 1957. More satellites of greater weight and carrying different types of equipment followed at short intervals. The USA, which also had included a satellite-borne experiments in her national IGY programme, first succeeded in completing the mission only on January 31, 1958. The IGY investigations conducted by Soviet and US scientists with the aid of satellites led to a number of important discoveries, including that of the RADIATION BELT OF EARTH.

Spacecraft built and sent into space in the USSR since 1957 have included satellites, automatic interplanetary stations and manned spaceships. Among the space developments have been the launching in the direction of the Moon of a rocket moving at a speed exceeding the second cosmic velocity and becoming a man-made planet and of a rocket that was the first to reach the Moon. An automatic interplanetary station, launched towards the Moon, sent back pictures of the lunar far side. Systems of future manned spaceships were tested on heavy satellite-spaceships orbited with animals or other living beings aboard. On April 12, 1961, the Soviet pilot-cosmonaut Yu. A. Gagarin achieved a historical breakthrough by orbiting the Earth in a spaceship. He was followed into space by other Soviet cosmonauts, each succeeding flight being a new step forward in the solution of problems of increasing complexity; in their flights new records in spaceship weight, altitude, duration of flight, and intricacy of experiments were achieved. Orbited was V. V. Tereshkova, the first woman to go into space. The *Voskhod* three-seater spaceship carried into space the pilot-cosmonaut V. M. Komarov, the scientists K. P. Feoktistov and the physician B. B. Yegorov. Finally, on March 18, 1965, the pilot-cosmonaut A. A. Leonov flying in the *Voskhod-2* became the first man to step out into space, and the pilot-cosmonaut P. I. Belyayev used manual control in landing the spaceship on March 19. 1967 witnessed the first automatic docking of spaceships in orbit around the Earth. The manned space programmes were paralleled with further development and launching in the direction of Mars, of Venus and of the Moon of automatic stations which brought back a wealth of scientific information. The Soviet automatic interplanetary stations, *Luna-9* and *Luna-13*, were the first to soft-land on the Moon (February 3, 1966, and December 24, 1966, respectively) and send back TV pictures of the lunar landscape. The *Luna-10*, the first man-made lunar satellite (April 3, 1966), was successfully followed in the same year by two other similar spacecraft—the *Luna-11* and *Luna-12*, and later on, by *Luna-14*. *Zond-5* and *Zond-6* automatic interplanetary stations made in 1968 the first round-the-Moon trip that brought back to Earth a wealth of scientific data. Four Soviet automatic interplanetary stations entered the bottom layers of the Venusian atmosphere, and three of them sent back to the Earth data on the properties of the planet's atmosphere.

Along with a large number of Earth satellites designed for space exploration, the USA successfully launched automatic interplanetary stations on

fly-by missions to Venus (*Mariner-2* and *Mariner-5*) and to Mars (*Mariner-4*), the latter sending back pictures of Marsian landscape taken at a fairly close distance. The spacecraft for the exploration of the Moon launched in the USA include the *Ranger*, the soft-landing *Surveyor* and a series of *Lunar Orbiters*. Two US manned space projects—the *Mercury* and the *Gemini*—have been completed, which included space walks and the first manually controlled orbital docking. The flight of *Apollo-8* around the Moon and back to Earth (December 21—27, 1968) was an outstanding achievement. The spaceship accommodated F. Borman (command pilot), J. Lovell and W. Anders. A more complicated flight round the Moon and back to Earth was performed by *Apollo-10* carrying T. Stafford (command pilot), J. Young and E. Cernan. The *Apollo* lunar excursion programme is nearing consummation. France joined the space club in 1965. ESRO and Japan are to orbit Earth satellites by home-made launch vehicles in 1969.

In view of the universal importance of findings made by space science and actual space exploration, the USSR has repeatedly made proposals on a world-wide basis for joint action to assure the use of outer space for the welfare of mankind. Accordingly, the UN adopted a resolution for the exclusive use of outer space for peaceful purposes (see SPACE LAW).

Progress in space exploration and successful manned space flights have spurred on the activities of national space societies, the establishment of government agencies responsible for the elaboration and implementation of national space programmes, the origination of a variety of research projects, etc. Under this heading come the Commission on Exploration and Use of Outer Space at the Academy of Sciences of the USSR and the NASA in the USA. An important part in space exploration is played by Academies of Sciences, universities, research centres and industry.

Considerable prestige is enjoyed today by international organizations, *viz.*, the International Astronautical Federation and COSPAR, whose work promotes useful exchange of ideas and information about achievements in cosmonautics, formulation of the primary problems, as well as the bringing together of scientists of different countries and their international collaboration. Within the general framework of international agreements a number of programmes and projects have been adopted and are being implemented on an international basis. Reflecting the immediate tasks and problems facing space exploration, these programmes and projects come roughly under two headings: (1) those directly related to the engineering aspects involved in launching space hardware, and (2) experiments conducted in space or as part of investigations of extraterrestrial objects. This division is purely arbitrary because the success of a research project depends on the perfection of every element in the launching and flight of a spacecraft, while the purpose of the experiment determines the hardware design which may have to be altered or improved in consequence of the actual findings. The principal aim of the scientific side of modern space programmes remains the attainment of an essentially new level of knowledge of the Universe and its laws through the use of spacecraft. The automatic control, memory units, communication systems and other types of equipment are so ingenious that in a number of cases an automatic interplanetary station becomes a true space explorer.

However, the dominant role in space exploration, to say nothing of its conquest, belongs, undoubtedly, to Man.

Some of the immediate problems facing space science include a study of the origin and present state of the Solar system as well as some aspects of inter- and extra-galactic astronomy. These problems concern primarily the chemical composition and physical characteristics of the atmospheres and surfaces of the planets and satellites, investigation of their geologies, more accurate data on the size and mass of the bodies of the solar system, analysis of the distribution and flow of solar corpuscular and electromagnetic radiation and of magnetic fields and space dust within the solar system. The initial stages of this research took the form of measurements made by space probes and automatic interplanetary stations. Outside the solar system research will focus primarily on the physical properties of interstellar space, the origin of cosmic rays, the study of the stars and nebulae, checking of the scale of interstellar distances, etc. Space flights also provide an opportunity for experimental verification of the theory of relativity.

The nearest future will witness the launching of more satellites carrying a variety of automatic equipment. The widest scope of study falls to Earth satellites carrying geophysical and astrophysical experiments. Increased emphasis will be placed on meteorological satellites destined to form the backbone of a world-wide weather system, geodetical satellites which will help specify locations on the face of the globe, communications satellites, both reflector and, predominantly, repeater types, a sufficient number of which will eventually form a network of world-wide TV and fail-free intercontinental telephone and telegraph communication. Other uses for Earth satellites will be indicated by the needs of science and practical "earthly" requirements. The establishment of permanent near-earth MANNED ORBITAL STATIONS will permit the solution of important problems on a more advanced level. Along with weather observations, newly-made-possible activities will include constant oceanographic investigations, monitoring of the movement of icebergs, heat flows and currents, even the movements of fish shoal, etc. Crew members will be brought to the orbital station by a ferry rocket which can later be used to take them back to Earth. Orbital stations will play a major role in the training of pilots of interplanetary spaceships in the future. Perfection of various manoeuvres, particularly approach and docking, work outside the space station, and assembly of structures in orbit, are possible only in space. Prolonged stay of researchers who have not been trained for weightlessness will make it necessary to spin the stations around a certain axis to give it artificial gravity. An orbital station alone can provide the required environment for the very intriguing experiment of growing plants under conditions of complete or almost complete weightlessness. Lunar soft-landing stations and Moon satellites will have a major role to play in the preparation of man's travel to the Moon.

A serious problem is presented by re-entry into the atmosphere. The re-entry trajectory must be sufficiently flat to avoid fatal overloads, nor can it take place too high above the Earth lest the rarefied air fail to hold the spacecraft which will then again escape from the Earth's atmosphere. These considerations make it imperative that the spacecraft be piloted into a nar-

row RE-ENTRY CORRIDOR. In travel to the Moon the big question mark is power. According to calculations the take-off weight of the launch vehicle in this case should be of the order of several thou. t. The construction of such colossal rockets presents enormous difficulties. According to the plan the lunar spaceship is assembled on a near-Earth orbit from materials delivered by supply vehicles, and after fuelling is launched from a certain point in orbit into the trajectory for reaching the Moon. According to another method the total mass that must overcome terrestrial gravitation and head for the Moon is reduced, in which case whatever equipment is not required on the Moon is left behind on the near-lunar orbit to be picked up on the way back to the Earth. This mass represents the amount that need not be landed softly and later lifted from the Moon surface. This reduces considerably the amount of propellant required for slowing down in landing on and starting from the Moon, which in turn saves a lot of propellant when launching the rocket vehicle from the Earth and minimizes the take-off weight of the latter. However, difficulties arise due to the need for docking on the lunar orbit and the limited choice of landing sites on the Moon. Manned conquest of the Moon will take quite an epoch in the history of space exploration. In the early stages the short stay of spacemen on the Moon will limit the size of the area investigated. Subsequent developments will include drilling the lunar surface to depths of hundreds of m, installation of large optical and radio telescopes, provision of oxygen, water and other types of generators using lunar rock for raw material. Self-propelled lunar vehicles will be able to travel hundreds of km away from the station.

The study of Mars and Venus, begun with the aid of automatic interplanetary stations passing at fairly small distances from these planets, will be continued using spacecraft of similar purpose, direct probes into their atmospheres, man-made satellites and soft-landing spacecraft. Only soft landing on Mars and on Venus can provide authentic information on the composition of surface materials, the temperature and moisture content of the lower layers of their atmospheres and the presence of life there. In the cases of Mars and Venus atmospheric drag can be made use of to slow down the landing spacecraft.

Landings on Jupiter, Saturn, Uranus and Neptune are apparently unlikely for the time being. Analysis of the atmospheres of the first two giant planets will require spacecraft built for very high pressures.

The exploration of the planets and their satellites will, doubtlessly, give us many unexpected surprises. Man may find forms of life which will be very different from those existing on the Earth and discover solutions to mysteries which are so intriguing now. These include not only the famous "canals" of Mars and the presence of life on that planet, but also the enigma of the "red spot" on Jupiter, of the sources of powerful radio signals emitted by certain parts of its surface (or atmosphere) and many others. The study of the distant planets poses the big problem of excessive duration of flights, using chemical or even nuclear rockets. The time of flight would be greatly reduced through the use of electric rocket engines which in the case of Pluto would require 3 years or less. At the present technological level, systematic study of the distant planets in any other way is impossible.

Asteroids and comets present another interesting class of objects for scientific investigation. Passing close to an asteroid or a comet and photographing it at close range, particularly if the space body is near the Earth's orbit, is no problem even today. Fig. 1 shows a characteristic trajectory of approach of a space station to a comet. Approach occurs at the intersection of the comet's orbit with the plane of the ecliptic—an essential point, considering that escape of a station from the plane of the ecliptic requires enormous power. To be able to follow a comet and study it over a prolonged period of time, an automatic space station would require such tremendous speed as will not be achieved for quite some time.

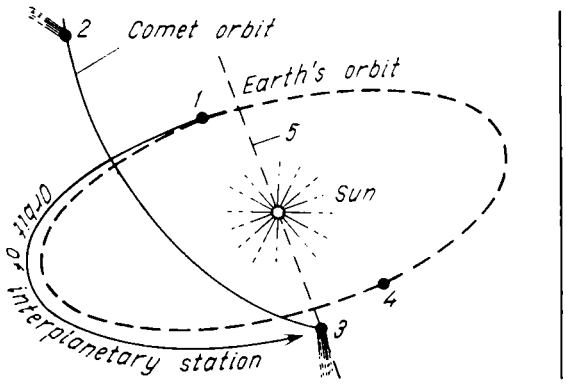


Fig. 1. Flight path of automatic interplanetary station aimed at impacting a comet.
1—Earth at time of station launch; *2*—comet at time of station launch; *3*—point of station impact on comet; *4*—Earth at time of impact; *5*—crossline of comet orbital plane with plane of ecliptic.

Studies of matter found in areas distant from the plane of the ecliptic would be of great interest. However, launches into trajectories forming wide angles with the plane of the ecliptic are bound to remain impracticable for a long time to come. At small angles of inclination an automatic interplanetary station will, nevertheless, be able to move millions of km away from the plane of the ecliptic but that will occur far from the centre of the Solar system. The areas immediately "above" and "under" the Sun will long remain inaccessible. Anyway, flights into near-Solar areas even in trajectories within the plane of the ecliptic raise enormous difficulties since they would require tremendous power expenditure. On the other hand, investigation of areas somewhat farther away from the Sun, within the Mercury orbit, will soon be a practicable matter, and one of great interest.

Not all the planets can become the field of work of future space expeditions. Thus, natural conditions on Jovian planets pose great hardships to the presence of men there (on Jupiter, moreover, gravity exceeds terrestrial gravity 2.6 times). Because of their adverse natural conditions, Mercury and, as it appears now, Venus, will be studied primarily by means of automatic stations. However, Mars and planetary satellites cause no such apprehensions and they, at least, are destined to become the working ground of future expeditions.

The duration of man's stay on other planets cannot be arbitrary since take-off for returning to the Earth is practicable only in a particular position of our planet and the given celestial body with respect to the Sun. Fig. 2 shows the diagram of an expedition to Mars using Hohmannian trajectories (see HOHMANN) on the way out and back (259 days one way). The "waiting time" for a Martian expedition is 450 days, thus the full duration of the pro-

ject will be 259 + 450 + 259 = 968 days, or 2 years and 8 months. This long duration of the expedition period necessitates heavy payloads to be carried by Mars-bound rockets. Corrected for gravitation and drag losses and manoeuvering impulses, the characteristic velocity of a Mars-bound rocket (by-passing launch from Mars surface into an areocentric orbit) should be approximately 20 km/s, or about the same as for a Moon rocket. However, the increased payload brings the take-off weight of a chemically-powered Mars-bound rocket up to tens or may be hundreds of thou. t. Any attempt to reduce the duration of an expedition will only result in greater characteristic velocity. Fig. 3 shows the diagram of a 456-day long Mars expedition:

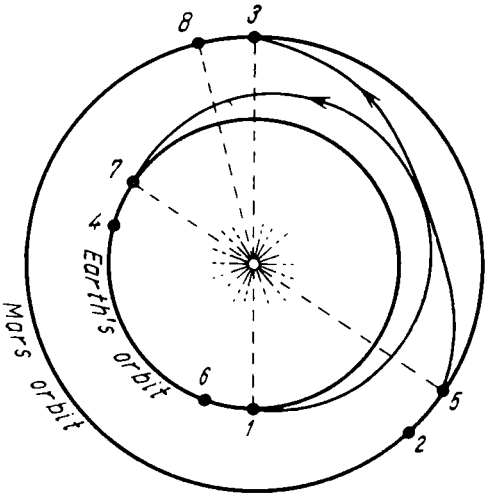


Fig. 2. Hohmann trajectories for Mars expedition.

1—start; *2*—Mars position at start; *3*—arrival at Mars; *4*—Earth at this moment; *5*—departure from Mars: *6*—Earth at this moment; *7*—return to Earth; *8*—Mars at this moment.

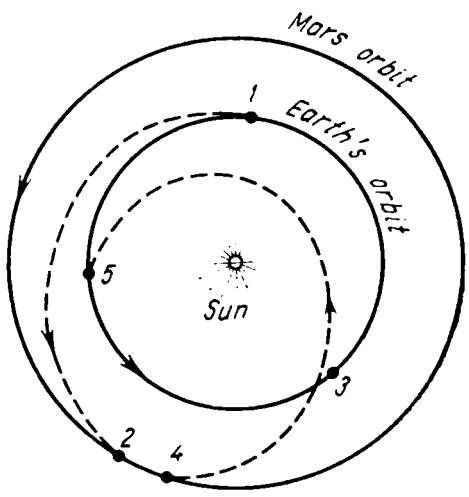


Fig. 3. Diagram of Mars expedition with 20-day stay on Mars.

1—start; *2*—arrival at Mars; *3*—Earth position at this moment; *4*—departure from Mars; *5*—return to Earth.

take-off from the Earth, December 28, 1981; arrival on Mars, August 4, 1982; return take-off, August 24, 1982; return to the Earth, March 29, 1983 (*Astronautics and Aeronautics*, 1965, vol. 3, No. 11). For this reason manned projects for Mars envisage assembly of spaceship from elements delivered by supply vehicles to a nearth-Earth orbit. Specifically, the above project for a Mars expedition in 1981—83 provides for 10 *Saturn-5* rockets to be launched into a near-Earth orbit, the spaceship being started from the parking orbit, manoeuvred to orbit around Mars and returned to the Earth by nuclear rockets using hydrogen as the working fluid. For purposes of accident prevention the authors of many projects for flights to Mars provide for simultaneous take-off of several spaceships from a parking orbit around the Earth. Some of them are supply rockets intended for the transportation of propellant for the flight back, a landing glider, etc. The use of low-thrust engines with a high specific impulse would be a great advantage in interplanetary travel. Such a spaceship could be put into orbit around the Earth with the aid of

a powerful launch rocket or be assembled in orbit. Then the spaceship is manoeuvred along a spiral away from the Earth's gravitational field followed by a spiral (consisting probably of a single incomplete loop) round the Sun. To allow the ship to be captured by the gravitational field of the planet of destination, it is slowed down before entry into the activity sphere of the planet and then spiraled down into a low orbit. On the return journey after

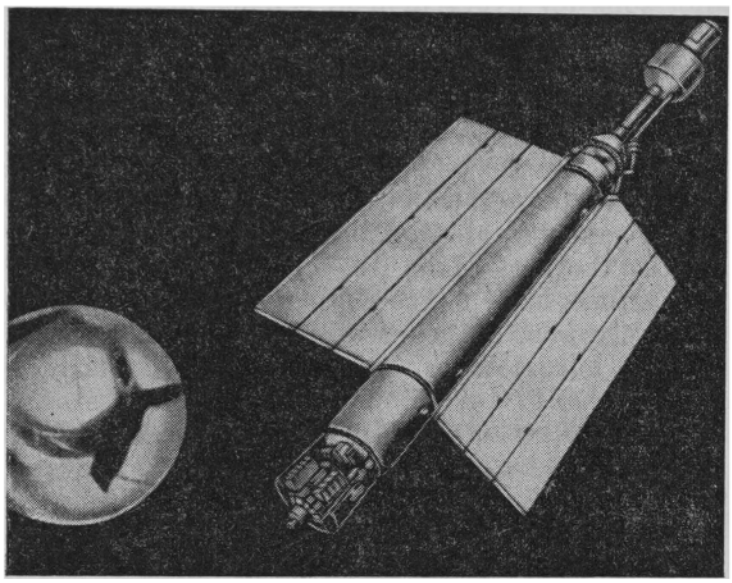


Fig. 4. Electrical rocket ship near Mars (mockup). The nuclear reactor is situated in the nose (upper part of this figure), plasma engines are in the tail. The rectangular plates are radiators for irradiating excess heat.

the expiration of the waiting time, unless the spaceship is intended for re-use, a low near-Earth orbit is by-passed for direct re-entry into the atmosphere at about the second cosmic velocity. In a low-thrust spacecraft the payload accounts for a considerable part of the vehicle's original mass.

Low-thrust interplanetary spacecraft may be used as cargo carriers. For travel to distant planets electrically-powered vehicles (Fig. 4) may well prove to be a better choice than thermonuclear craft both in terms of payload capacity and flight duration. Liquid-propellant rockets will be used in the 1st stages of spaceships for landing on and lift-off from the celestial body being investigated, cosmic velocities in the 2nd and 3rd stages will be achieved with nuclear rockets, while electric rockets will go into service only for travel between planets.

Another set of problems open to solution through exploration of space concerns the origin and evolution of life forms. A discovery within or outside the Solar system of life in any evolutionary stage, or at least of remnants of life, would provide an invaluable opportunity for a deeper study of this problem which alongside with the problem of the origin of celestial bodies is a matter of great importance for philosophy.

Space travel affords extremely rich opportunities for medico-biological studies in the environment of space flight and of other planets. In view of the requirements posed by exploration and conquest of extra-terrestrial objects, space programmes include studies of the properties of materials and structures under conditions widely different from those on the Earth, development of life support systems, and many other scientific and technical problems which for lack of space cannot be listed here. Indeed, space flight opens up unprecedented horizons for every field of science and technology. Also, the fact that in some cases space flight permits the speeding up of the solution of certain problems, compared with the amount of time that would be required under conditions on Earth (e.g., investigation of the shapes of the Earth and the Moon or collection of weather data) and makes possible a variety of space experiments, adds to its importance for scientific progress as a means for quicker and deeper penetration into the secrets of Nature.

Space flight has a considerable and favourable effect on progress in industrial production. In the first place, the very preparation and implementation of space programmes have led to rapid progress in, and in some cases to origination of, entirely new branches of technical knowledge in such fields as power engineering, automation, radio electronics, metallurgy, mechanical and instrument engineering, development of novel food-stuffs, etc. Progress in any of these fields does not only help space exploration, but also aids man in his work and activities here on Earth. With man's landing on the Moon and the planets and the beginning of space conquest at large, the scope and complexity of tasks facing industry will increase still more. However, the part played by cosmonautics in industrial progress is not limited to promoting the emergence of new tasks. Our times are increasingly characterized by the use, in industrial production, of forces and processes which can justifiably be regarded as belonging outside the strictly earthly class of phenomena, e.g., nuclear reactions, magnetohydrodynamic phenomena, super-high vacuum and temperatures, X-rays and other kinds of high energy radiation, etc. Space flight is the only opportunity to study these phenomena and their characteristics in the native conditions, in the laboratory of the Universe.

Finally, of immense importance to Man is the opportunity space flight affords for progressing from the exploration of space and space objects to the organization of production in cosmos and later to intensive utilization of cosmic energy and natural resources for Man's welfare. Industrial production in space is rooted in the concept of prolonged manned flights to extra-terrestrial objects because neither all the elements of such flights nor all of the spaceman's needs can be supplied out of the Earth-provided cargoes. Conversely, as the mining and other industries develop in space, e.g., on the Moon, their products will be used for the needs of the Earth's population.

Considerable advantages are inherent in the use of space technologies for Man's immediate welfare, including rocket transport vehicles powered by new types of space engines, a global communication system based on Earth satellites, a world-wide weather system, application in geodesy, navigation, etc. Among the initial steps made in this direction are the first communications and meteorological satellites and other projects, although widespread and direct use of space technology in the planet's life is still in its earliest stage.

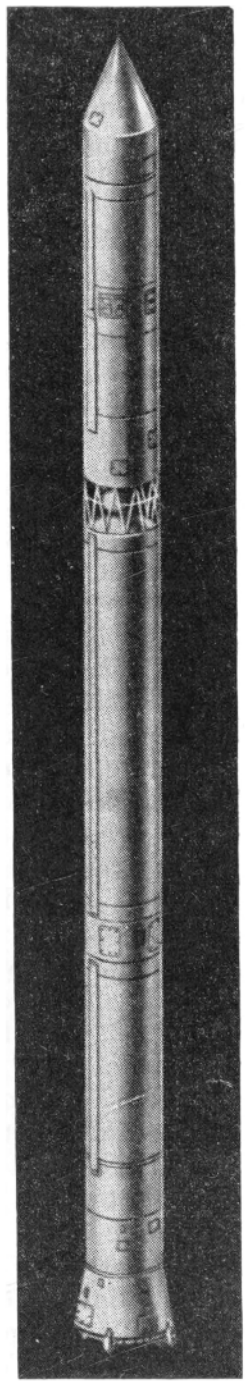
Thus, advances in cosmonautics based on progress in science and technology, provide a powerful stimulus to engineering and industrial progress.

K. E. Tsiolkovsky believed that population growth and engineering progress will cause mankind to expand outside the confines of the Earth and into outer space. "The Earth is the cradle of Mankind, but one cannot live in a cradle forever", wrote he. Human settlement outside the Earth and gradually all over the solar system will necessitate establishment of industry in space. The power requirements of future space settlements, for which Tsiolkovsky suggested a plan of organization and management, may be met by the Sun's energy.

Along with the recent successes in cosmonautics *viz.*, Man's first step into space and the increasing distances from the Earth reached by manned and pilotless spacecraft. Man is seeking other ways of learning about the Universe. These include the idea of search for EXTRATERRESTRIAL CIVILIZATIONS and of the establishment of INTERSTELLAR COMMUNICATION. True, the first attempt to receive signals from extraterrestrial civilizations (OZMA PROJECT) did not meet with success, but the concept of interstellar communication is bound to go on developing as a prospective way to achieve a fuller picture of the Universe. Although a search for extraterrestrial civilizations is not directly related to present-day cosmonautics, the discovery of such a civilization would not only be of tremendous importance to philosophy, but would also play a great practical role in progress of space science.

COSMOS. A synonym for the Universe, also used in the sense of outer SPACE, with all its objects; it includes circumterrestrial, interplanetary, interstellar and intergalactic space and its entire population.

COSMOS LAUNCH VEHICLE. A Soviet two-stage launch vehicle which has been used since March 16, 1962, to place *Cosmos* satellites into orbits. The stages of the *Cosmos* launch vehicle are arranged in sequence; its total length is 30 m and dia, 1.65 m. The first stage is powered by an *РД-214* engine burning nitric acid as oxidizer and hydrocarbons as fuel to produce a thrust of 74 t. The final stage is provided with an *РД-119* rocket engine with a thrust of 11 t, which fires LOX and unsymmetrical dimethyl hydrazine. The satellite is mounted on the final stage beneath the nose cone which is jettisoned in the launch phase after passing through the dense layers of the atmosphere. At the end of the launch phase, the satellite is jettisoned from the upper stage. The *Cosmos* launch vehicles were used to launch a great number

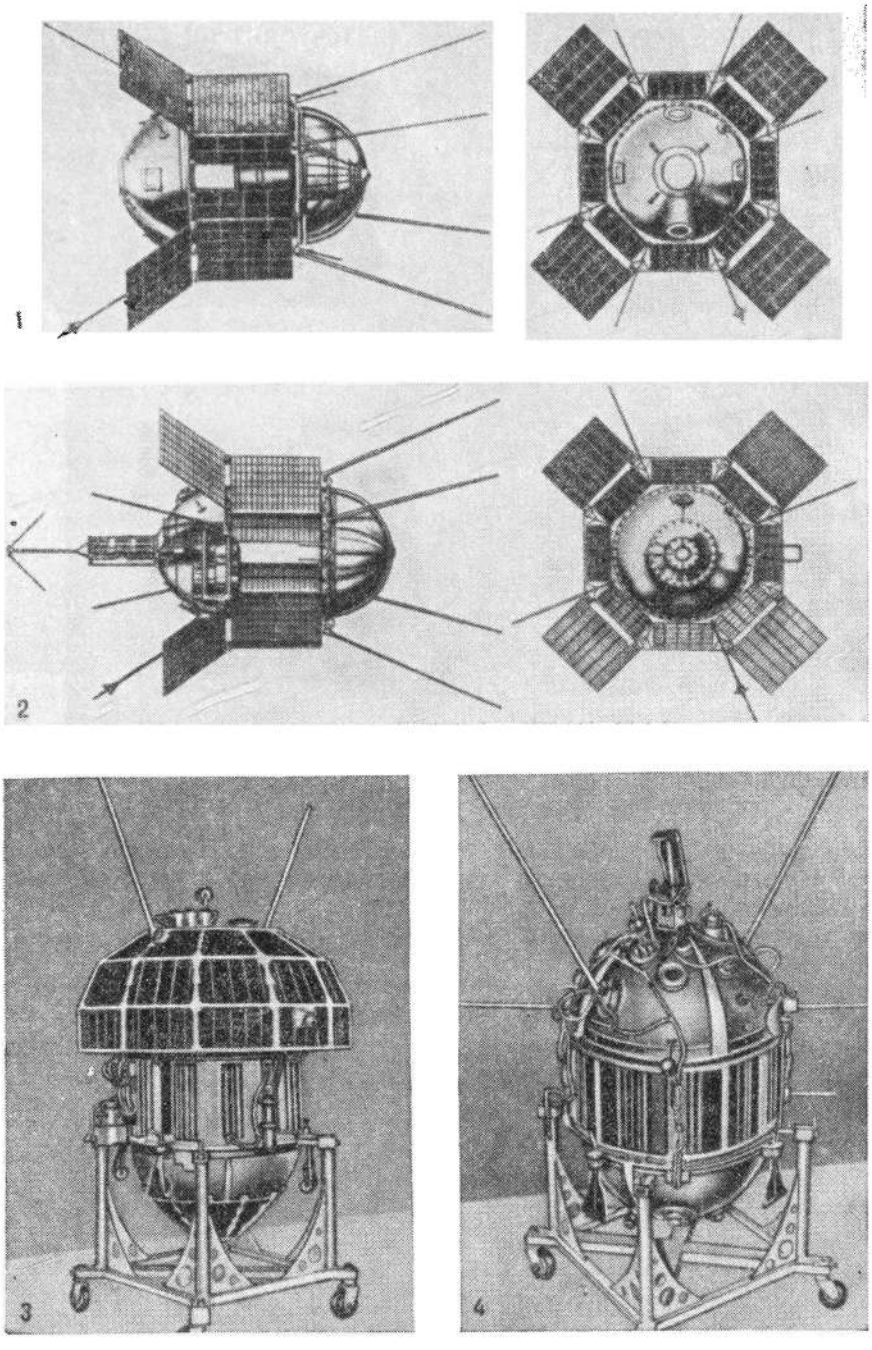


Cosmos launch vehicle.

of Soviet satellites for investigation of circumterrestrial space, the upper atmosphere, etc.

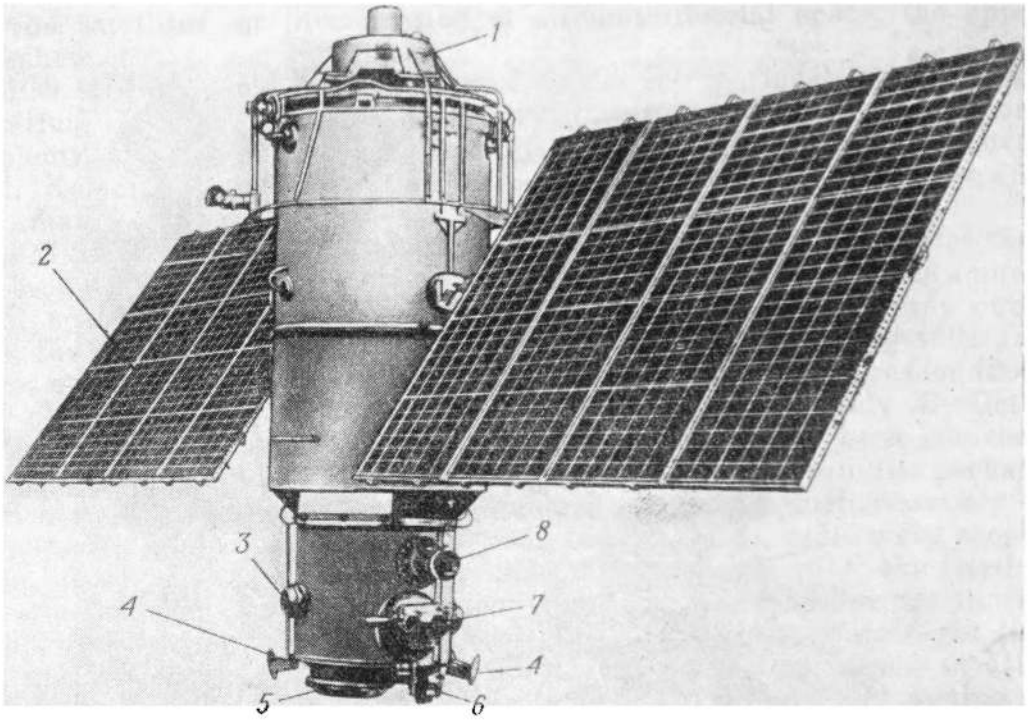
COSMOS MEDAL. Gold medal presented by the International Astronautical Federation since 1963 for outstanding contributions in space exploration. Recipients are A. G. Nikolayev, P. R. Popovich, V. V. Tereshkova, V. M. Komarov, K. P. Feoktistov, B. B. Yegorov, A. A. Leonov and F. Borman.

COSMOS SATELLITES. The name of a series of Soviet Earth satellites that have been regularly injected into orbit by various launch vehicles from a number of space centres since March 16, 1962; their purpose is to study outer space, the upper layers of the atmosphere and the Earth. During 1962 and 1963 as many as 24 *Cosmos* satellites were sent into orbit; the figures for 1964, 1965, 1966, 1967 and 1968 were 27, 52, 34, 61 and 64, respectively. By October 4, 1967, the number of satellites in this series that had been launched into space was 180, and by Oct. 4, 1969, it grew to 301. The satellite package varies according to its mission. The research programme includes study of the concentration of charged particles, corpuscular fluxes, radio wave propagation, distribution of the Earth's radiation belt, cosmic rays, the Earth's magnetic field, solar radiation, meteoric matter, cloud formations in the Earth's atmosphere, solution of technological problems of space flight (in-orbit docking, atmospheric re-entry, effect of space factors, means of attitude control, life support, radiation protection, etc.), and flight testing of many structural elements and spaceborne systems. The *Cosmos* satellites orbit at altitudes ranging from ~145 km to 60,600 km (*Cosmos-260*). A single launch vehicle sometimes injects into orbit several satellites (*Cosmos-38* through *40*, *Cosmos-71* through *75*, *Cosmos-80* through *84*). The *Cosmos* satellites are highly diversified in design and carry various systems and equipment. Many of them are oriented either towards the Sun or towards the Earth (using, in particular, the aerodynamic system of orientation). Solar batteries or chemical sources of energy are employed (nuclear-isotope batteries have also been tested). Scientific data and measurements are relayed to Earth by multi-channel telemetry systems equipped with space-borne memory units. Certain satellites in this series (e.g., *Cosmos-110*, *Cosmos-186* and *Cosmos-188*, etc.) incorporate re-entry bodies (capsules) for landing scientific instruments and test objects. A number of *Cosmos* satellites are of unified design and have similar systems on board, thus permitting easy substitution of scientific instruments for different flight missions. The *Cosmos-1* and *Cosmos-2*, the first satellites in this series, employed radio methods to study the structure of the ionosphere. *Cosmos-3* and *Cosmos-5* were automatic geophysical stations. The mission of *Cosmos-4* was measurement of radiation before and after the US nuclear tests conducted according to project *Starfish*. Radiation measurements made by *Cosmos-7* guaranteed safety during the flight of the *Vostok-3* and *Vostok-4* spaceships. *Cosmos-26* studied the geomagnetic field. *Cosmos-97* carried out experiments with a maser, which are of importance in long-distance space communications. The *Cosmos-110*, a biological satellite, made a sustained biomedical experiment with the dogs Veterok and Ugolyok; after 22 days in orbit round the Earth they were safely landed. The *Cosmos-122* tested equipment for weather observation. The



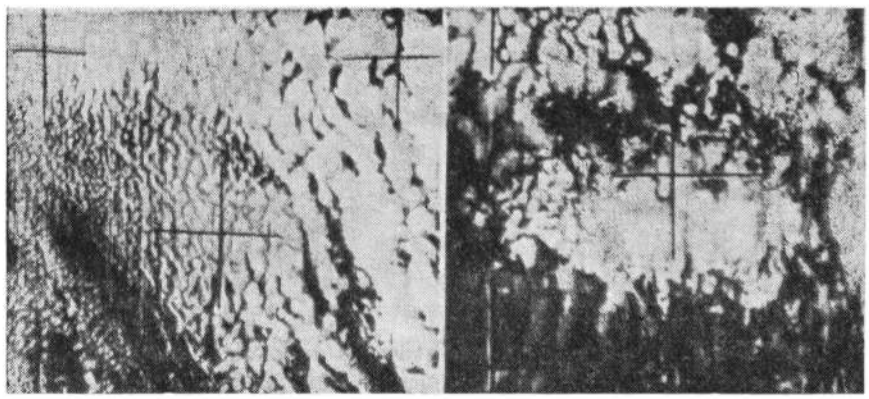
Some satellites of the *Cosmos* series.

1—*Cosmos* for investigation of Earth radiation belt; *2*—*Cosmos* with a molecular generator on board; *3*—*Cosmos* for investigation of low-energy particles; *4*—*Cosmos* for ionospheric studies.



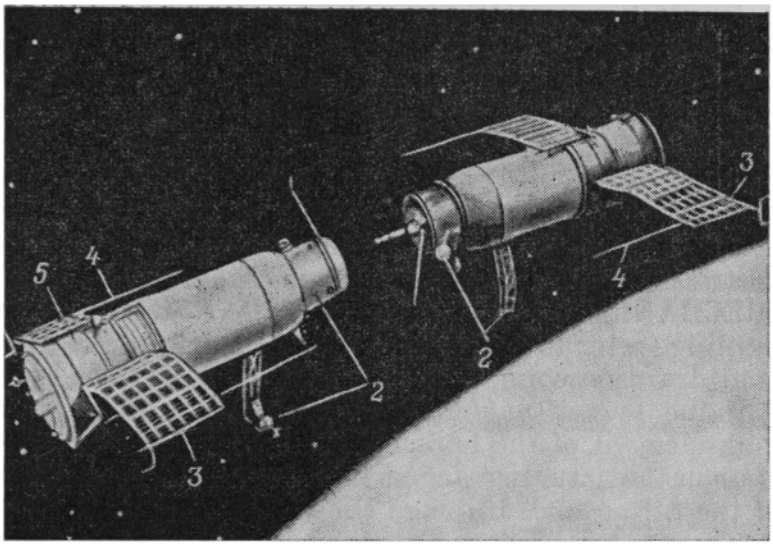
Cosmos-144 satellite comprised in *Meteor* system.

1—servo mechanism of solar battery orientation; *2*—panels of servo batteries; *3*—orbit control equipment; *4*—antennas; *5*—TV cameras; *6*—magnetic sensor; *7*—receiver of actinometric equipment; *8*—receiver of IR equipment.



Cumulus nebulosity in the rear of cyclone over Yakutia, photographed by *Cosmos-122* on July 17, 1966, at about 10 a. m. Moscow time.

Soviet meteorological satellites *Cosmos-144*, *Cosmos-156*, *Cosmos-184*, *Cosmos-206* and others, comprising part of the *Meteor* system, regularly supply meteorological data for the weather service. Automatic approach and docking of satellites in orbit was accomplished on October 30, 1967, by *Cosmos-186* and *Cosmos-188*; after separation these two satellites continued to fly independently and then landed on the territory of the USSR. *Cosmos-212* and *Cosmos-213* were automatically docked in orbit on April 15, 1968; both these satellites also landed on Soviet territory. *Cosmos-261*, injected into orbit on



Automatic orbital mating of *Cosmos-186* and *Cosmos-188* satellites realized for the first time in the world on October 30, 1967. Automatically performed were mutual search, approach, mooring and docking. After 3.5 h of joint flight, the satellites parted in response to the command sent from the Earth and continued to fly separately. On October 31, 1967, *Cosmos-186* made a soft landing in the pre-set region. On November 2 *Cosmos-188* returned to the Earth. The figure shows the final stage of the satellite approach.

1—mating fittings; *2*—search and homing antennas; *3* and *5*—solar cell batteries; *4*—radio complex antennas.

December 20, 1968, explored the upper atmosphere of the Earth and investigated the nature of aurorae. This experiment was a joint effort of research institutions and observatories of the People's Republic of Bulgaria, the Hungarian People's Republic, the German Democratic Republic, the Polish People's Republic, the Roumanian Socialist Republic, the Soviet Union, and the Czechoslovak Socialist Republic.

COSPAR (Committee on Space Research). Founded in 1958 by the International Council of Scientific Unions for the purpose of conducting space research on an international scale with the use of rockets and satellites. COSPAR includes representatives of 10 international scientific unions and 32 national Academies of Sciences. COSPAR has the following working groups: tracking, telemetry, dynamics; projects for and coordination of space experiments; data

and publications; properties of the upper atmosphere; space biology; space experiments dealing with studies of the properties of the troposphere and the stratosphere. It likewise includes an advisory group that handles problems of the potentially harmful effects of experimentation in outer space. COSPAR annually holds plenary meetings and international space science symposia associated with them. Periodic publications cover the results of COSPAR activities.

COUNTDOWN DIAGRAM. Graphs and tables that describe the operational sequence of a launch preparation activity beginning with the moment the space vehicle leaves the vehicle assembly building and ending at the lift-off. The time necessary for performing each operation is indicated in the diagram. The countdown diagram is a visual representation of processes needed for the launch preparation and the launch proper of a space vehicle.

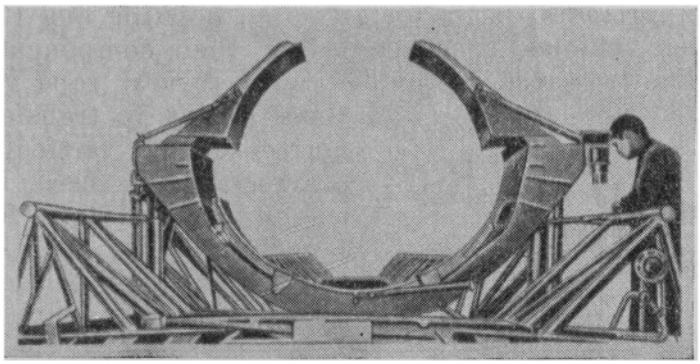
COUPLING MECHANISM OF ELECTRICAL CONNECTORS. A device used for remote coupling of the blocks of electrical connectors of the ground cable lines with the reciprocal blocks of the pad-mounted launch vehicle, for keeping these blocks in working position during the pre-launch period and separating the electrical connector blocks at launching.

COUPLING MECHANISM OF HYDRAULIC CONNECTORS. A device used for remote coupling (prior to filling the launch vehicle tanks with propellant) of the filler and drainage connectors of the ground servicer system with the filling necks of the launch vehicle. The coupling mechanism of hydraulic connectors is an element of the launcher. The design of the coupling mechanism depends upon the actual arrangement of the launch vehicle filling necks, the weight of the filling and drainage connectors and other factors. The filling and drainage connectors are moved by means of pneumatic, hydraulic, electric and spring actuating mechanisms, provision being made for stand-by manual operation.

COUPLING MECHANISM OF PNEUMATIC CONNECTORS. A device used for remote coupling of the blocks of pneumatic connectors of the ground pneumatic system with the reciprocal blocks of the pad-mounted launch vehicle, for keeping the pneumatic connector blocks in operating position during the pre-launch period and separating the blocks prior to launching. The coupling mechanism of pneumatic connectors is an element of the launcher and ensures a proper coupling within certain displacements of the launch vehicle from nominal position. The coupling of pneumatic connectors is facilitated by providing the latter with guide pins to enter the guide holes of the launch vehicle reciprocal blocks, thus ensuring proper alignment of the connector blocks. The design of the coupling mechanism depends upon the actual arrangement of the launch vehicle reciprocal blocks, the weight of the pneumatic connector block, the conditions of protection of these blocks against jet impingement and other factors. The pneumatic connector blocks are joined together and separated by means of pneumatic, hydraulic and electric actuating mechanisms and springs.

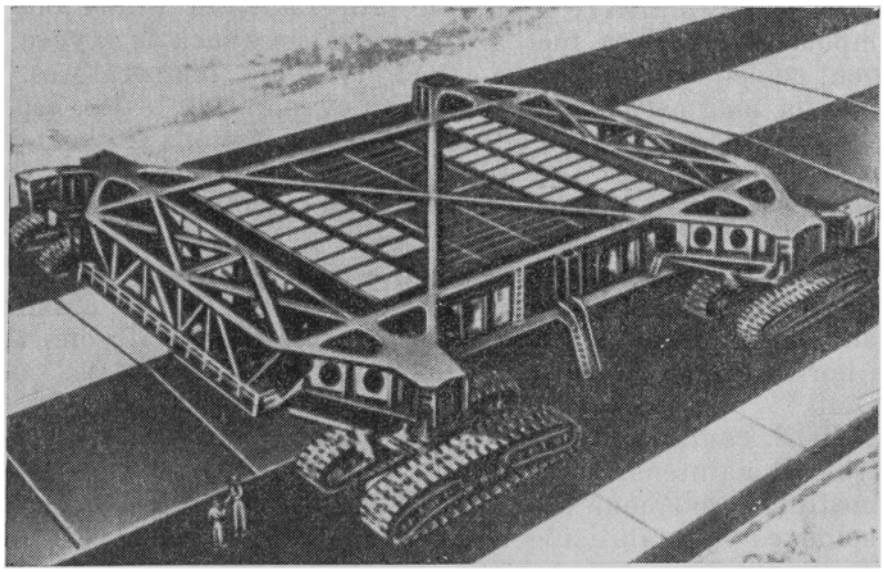
CRADLES. A commonly used support for securing a space vehicle, a launch vehicle, a space body or their stages and modules on transport facilities and erector arms. The cradles are metal structures whose supporting surfaces are shaped to match the profile of the space vehicle shell; on these supporting

surfaces rest the load-carrying sections of the launch vehicle or spacebody (or rings slipped on them). The supporting surface of the cradle is lined with felt or rubber corrugated pads to prevent the launch vehicle against mechanical damage. The cradles are fitted with grips or braces to fasten the rockets in transit and during erection.



Cradle with grips for securing a rocket in transport position.

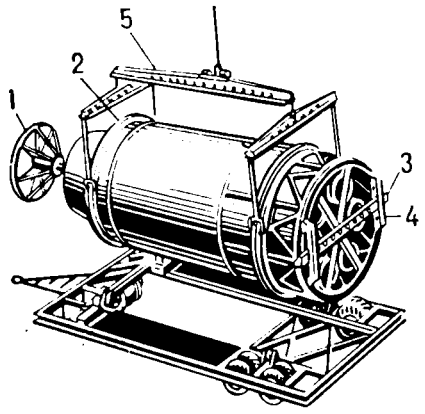
CRAWLER TRANSPORTER. A vehicle for carrying heavy launch vehicles in the vertical position from the vertical assembly building to the launch pad of the space centre. The transporter has a load-carrying capacity of up to 5500 t and a travel speed of 1.6 km/h when fully loaded. The crawler transporter is, essentially, a lifting frame installed by means of hydraulic jacks on four twinned crawler bogies. Mounted on the lifting frame is a launching platform on which the launch vehicle is assembled in the vertical position.



Crawler transporter for carrying an erected rocket from the vertical assembly building to the launching site (USA).

While the crawler transporter with the launch vehicle is moving to the launch site, the hydraulic jacks are controlled by a stabilization system that keeps the launch vehicle longitudinal axis vertical within ±5 angular minutes. Upon arriving at the launch site, the launch platform with the launch vehicle is transferred by hydraulic jacks from the crawler transporter onto the launcher supports.

CROSSARM. A horizontal beam for gripping, hoisting and transporting the assembled launch vehicles, space bodies or their components by means of a crane hook. The crossarm is provided with several rope grips and sometimes allows to transfer the load in horizontal and vertical planes. A set of crossarms is used in the vehicle assembly building for assembling launch vehicles.



Crossarm application for hoisting a rocket stage.
1—front support ring; *2*—bandages; *3*—pivots; *4*—rear support ring; *5*—crossarm.

CROSSFEED. Pipeline for draining air and liquid vapours from the tanks being filled into the supply tank. Crossfeed is used only in the case of pump feeding, when the vapours of the propellant components are poisonous or the mixture of oxidizer and fuel is dangerously explosive and therefore should not be ejected into the atmosphere, as stipulated by safety regulations.

CRYOGENIC PROPELLANT. A liquid propellant, in which one or both of the components (oxidizer, fuel) are liquefied gases such as oxygen, fluorine, or hydrogen, cooled to very low, so-called cryogenic, temperatures. They are not storable for long periods of time due to evaporation losses, especially in outer space conditions, because of the weight limitations for heat-insulating facilities. Therefore, cryogenic propellants should be used only in those cases when this is warranted by an increase in the specific impulse obtained as compared to that of STORABLE PROPELLANTS.

CULMINATION (transit). The passage of a celestial body across a meridian of the celestial sphere (twice in diurnal rotation). Upper culmination is passage across the meridian in the half (from the celestial pole) that intersects the horizon in the South point; lower culmination is the same in the North point.

CULTIVATION, continuous. A method of growing algae cultures, characterized by artificial maintenance of the most vital relations between the organism and the medium throughout the period of cultivation (days, weeks, months). This is achieved by stabilizing the main conditions, i.e., culture density, degree of illumination, temperature, concentration of elements of mineral nutrition and CO_2 in the medium, pH of the medium, etc., by using a continuous culture, from which the increment of biomass and products of metabo-

lism are continuously removed, while decrement elements of mineral nutrition and carbon dioxide are replenished from outside sources. Cultivation is a major method in management of biotechnical processes when culture productivity must be maintained at a pre-set level. In particular, this applies to the biological systems for BIOLOGICAL AIR REGENERATION and to the link of unicellular algae in a closed ecologic system of a spaceship.

CULTIVATION UNIT. A unit of a LSS intended for cultivating micro-organisms by batch or continuous method. The unit consists of one or several PHOTOSYNTHETIC REACTORS, sources of light or devices for light transmission from an outside source, a set of sensors, a gas circuit, and in some cases a device for separating and mixing liquids and gases, a drain-feed device (for continuous method) and devices for automatic recording and monitoring of pre-set parameters.

CULTURE MEDIUM. A medium in which micro-organisms are cultivated. It is their environment and source of food, oxygen, carbon dioxide, etc. Culture media are selected individually for each link of the BIOCOMPLEX. They are kept at optimum conditions by technical facilities.

CUNNINGHAM, Ronald Walter (born 1932, Curston, Iowa). US astronaut, major of Reserve Corps (retired). Served with the US Navy beginning 1950, where he learned piloting. Subsequently retired from the Armed Forces, but remained in the Marine Reserve. Received. B. A. and M. A. degrees in physics from the University of California at Los Angeles. As a research scientist at the Rand Corp., studied terrestrial magnetism. Joined the NASA group of astronauts in 1963. Was a member of the crew of the *Apollo-7* which made 163 orbits round the Earth on October 11—12, 1968.

CUT-OFF OF ROCKET ENGINE. The complex of transitional processes in a rocket engine from sending the command for cutoff to the complete thrust termination. The cutoff of a liquid-propellant engine is accomplished by a forced (regular) cessation of propellant supply to the combustion chamber and of the working fluid to drive the turbopump assembly or to pressure-feed the propellant. Solid-propellant engines are sometimes cut off by sharply reducing pressure in the combustion chamber.

CUT-OFF VALVE. A valve used in the hydraulic or pneumatic automatic control systems of a liquid-propellant engine, a spacecraft or a space centre and designed for shutting off rapidly and reliably the hydraulic or pneumatic lines. The closing time of the cut-off valve equals, as a rule, fractions of a second. It is actuated by gas, liquid, powder gases of pyrotechnic cartridge or by electromagnet.

CYLINDER BATTERY. See RECEIVER ROOM.

CYLINDER FEEDING OF PROPELLANT. See PRESSURE FEEDING OF PROPELLANT.

CYRANO DE BERGERAC, Savinien (1619—1655). French poet. Son of a solicitor. Attended Jesuit college, served in the Royal Guard for 2 years. In 1649 he finished *L'autre monde ou les états et empires de la Lune*, in 2 parts. The 1st was published in 1657 as *L'histoire comique contenant les états et empires de la Lune*, and the 2nd, in 1662, as *Les états et les empires du Soleil*. The author described 8 ways of reaching the Moon and 4 ways of reaching the Sun. One was by powder rockets fired in succession. A crater on the far side of the Moon has been named in his honour.

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Д-1-А-1100. The liquid-propellant engine of the *БИ-1* aircraft. It was developed by the Rocket Research Institute in 1941—1942. Captive tests were held from October, 1941, ground tests, on board the aircraft in April and May, 1942. Nominal thrust, 1100 kg; specific impulse, 203 s; pressure in the combustion chamber 19 at. Burning time in flight up to 200 s at alternating rate and up to 70 s at maximum rate. The service life, 18 min. The engine had a throttle system that could alter the thrust from 400 to 1400 kg. Propellant, nitric acid and kerosene; propellant feed, by pressure of compressed air; starting ignition, by an electric incandescent plug.

DAY. A unit for measurement of time, equal to 24 hours. A sidereal day is measured by the interval between two successive culminating positions of the VERNAL EQUINOX; a solar day, by that of the Sun. In science, engineering and practical life the so-called mean solar day is used, which is longer than the sidereal day by 3 min 55.91 s mean time.

DE-AERATION OF PROPELLANT. Removal of air from some of the propellant components filled into spacecraft. Achieved by means of vacuum treatment of the propellant or by blowing (bubbling) an inert gas, such as nitrogen or helium, through it.

DECALCIFICATION. Calcium loss by the organism in weightlessness because of excessive excretion of calcium from the skeletal system with urine and feces. An increase in the calcium content of the urine was found after the first orbital flights. According to American authors, the loss of calcium after an 8-day flight reaches 12—15%. In conditions of simulated weightlessness (e.g., immersion tests, long periods of bed-rest), the amount of calcium excreted from the organism at equal periods of time is several times less. Decalcification may lead to bone fractures by muscular exertion, functional disturbances and the deposit of calcium in various organs, particularly, the kidneys. Relative decalcification of the organism may be regarded as the result of general mineral-and-water dysbolism during space flight. All spacemen showed marked dehydration, and a weight loss of 3 to 4 kg. The dehydration of the organism is reflected in a certain hemoconcentration. The reduction in the amount of circulating blood involves an increase in the amount of erythrocytes. The effectiveness of physical exercises, medicines and rational nutrition as preventives against decalcification is being studied.

DECLINATION. A coordinate in the equatorial system of CELESTIAL COORDINATES: the arc of the great circle passing through the celestial pole and star, measured from equator to the star. Distinguished are positive (northern) and negative (southern) declination, measured respectively from 0 to $+90°$ or $-90°$.

DECLINATION CIRCLE. The great circle of the CELESTIAL SPHERE passing through the celestial pole and the luminary. The declination of celestial bodies is measured on the declination circle.

DECOMPRESSION SICKNESS. A condition caused by altitudinal decompression (drop in atmospheric pressure at an altitude of approximately 8000 m). The main symptoms are: pruritus, pain in the joints, vertigo, pallor, excessive perspiration, etc. Decompression sickness is associated with an increase in the amount of free gases (mainly nitrogen) in body cavities, and with the transition of the nitrogen dissolved in the tissues into a gaseous state. Decom-

pression sickness may result from depressurization of the spaceship cabin, as well as from tests in pressure chambers. The incidence and severity of decompression sickness depend on the degree of vacuum and the time the spaceman spends in these conditions.

DE-ODORIZATION. The elimination of odours originating in sealed spaceship cabins from storage and reprocessing of metabolic by-products as well as those given off by the polymers and the equipment. The metabolic by-products can be de-odorized by adding preservatives inhibiting fermentation and decay. The drinking water is treated with oxidizers (potassium permanganate, hydrogen peroxide, active chlorine, ozone) or is passed through activated carbon (de-odorizing extractor).

DESCENDING NODE. See ORBITAL ELEMENTS.

DESCENT PULSE. The pulse applied to the spacecraft to land it on the surface of a celestial body. The magnitude of the descent pulse depends upon the method of landing used. A relatively small pulse is required for re-entry with atmospheric braking. An Earth satellite can be landed by a descent pulse that reduces the velocity by 100—200 m/s. Landing of spacecraft on large planets lacking an atmosphere requires a descent pulse large enough to almost completely eliminate the spacecraft's velocity relative to the landing surface. Thus, some 1500 m/s must be eliminated to land a lunar satellite. As concerns power consumption, the most favourable direction of the descent pulse does not necessarily coincide with the direction of the tangent to the spacecraft's orbit, i.e., the direction of the BRAKING PULSE.

DESICCATION PLANT. An installation included into the compressor station of a space centre. It ensures drying of compressed gas or air to a relative humidity value corresponding to the required dew point. The plant comprises a system of high pressure cylinders filled with a highly porous adsorbent (silica gel, alumogel, zeolite, etc.), heating means for alternate reclaiming of adsorbents, and manifolds with shut-off and control fittings.

DESIGN OF ROCKET ENGINE. The theoretical determination of the parameters of basic steps in the working process of a rocket engine, and the major characteristics of the engine subassemblies and the engine as a unit, as well as the analysis of control ranges for thrust and fuel-to-oxidizer ratio, etc. The analysis of a rocket engine is preceded by the selection of the propellant in accordance with the purpose of the engine, and the selection of its layout. This is followed by an estimation of the optimum values of pressure in the chamber and the degree of gas expansion in the nozzle with due account for the weight equivalents of the engine, specific impulse and size. After certain sets of characteristics have been chosen, a complete analysis of the rocket engine is made. There are: a thermodynamic analysis of the processes in the combustion chamber and gas generators (determination of the thermodynamical parameters of the combustion products and the theoretical specific impulse), gas-dynamic analysis of the thrust chamber (determination of the actual specific impulse and the main parameters of the combustion chamber and the nozzle), calculation of the nozzle contour. Heat-transfer and hydraulic analysis of the cooling systems for the thrust chamber and gas generator, analysis of the injectors and mixing system, of pressure losses in the propellant-feed lines and manifolds, a hydraulic analysis of pumps, a thermodynamic

analysis of the turbine, an analysis of pumps and-propellant-feed system (e.g., of launchers, booster pumps with drives, fuel and oxidizer tanks pressurization units), pressure differentials at controls, etc., an analysis of automation units, an estimation of the influence of external and internal factors on the major parameters of the engine, an analysis of adjustment of the liquid-propellant engine for operation under nominal conditions, analyses of the starting procedure, of the thrust die-away, of the engine's amplitude-versus-frequency response characteristics, of operation stability, a dynamic analysis of controls, a strength analysis of individual units of the engine, etc. In view of the complexity of the rocket engine analysis and the great amount of work involved, analog and digital electronic computers of the most advanced systems are used.

DESORBER. A device for removing gases and vapours from the surface of solid porous absorbers (most extensively used in spaceship LSS) or from liquids. The adsorber is simultaneously a desorber (in the sorbent recovery cycle) if the sorbents are recoverable; in some air regeneration systems in sealed cabins the desorber and adsorber can be separate devices, e.g., in electrolysis of salt solutions and melts. Desorption is accomplished by raising the temperature of the sorbent, by means of vacuum evaporation, blowing an inert gas through the sorbent, as well as by a combination of these methods.

DETONATION. Combustion of a propellant at an extremely high rate exceeding the speed of sound and attaining the value of 8—9 km/sec in solid and liquid propellants, and 1—3 km/s in gaseous mixtures. Detonation is generated under the action of a shock, high-power shock wave, etc., where the magnitude of the charge exceeds the critical one. In rocket engines detonation can originate as a result of retardation of charge ignition which may occur in the combustion chamber on starting the engine, or under the action of shock waves produced when oscillation of the gas pressure is developed in the combustion chamber of the rocket engine (see SELF-EXCITED VIBRATION). Detonation is inadmissible because it results in the destruction of the combustion chamber. Investigations are being conducted to ascertain the possibility of its profitable utilization.

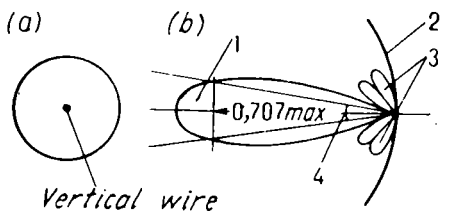
DEWAR FLASK. A container with double walls coated with silver inside. The space between the walls is evacuated so as to minimize the heat exchange between the environment and the substance inside the flask. Containers for LOX and other cryogenic liquids are designed according to this principle.

DIETHYL AMINE $(C_2H_5)_2NH$. A high-boiling fuel for liquid-propellant engines. A colourless volatile liquid having the odour of ammonia gas, density 0.706 g/cm^3 at 20°C; m.p., —48°C; b.p., 55.9°C. Proposed and tested as an effective fuel for liquid-propellant engines in combination with fluorine monoxide by GDL—OKB (1954).

DIMETHYL HYDRAZINE, unsymmetrical, $H_2N\text{-}N(CH_3)_2$. An extensively used fuel for liquid-propellant engines. A colourless, hygroscopic, high-boiling liquid of ammoniacal odour, absorbes oxygen and carbon dioxide from the atmosphere; density, 0.790 g/cm^3 at 20°C; m.p., —57.2°C; b.p., 63°C. Dissolves in water, hydrocarbons, and other solvents. Poisonous. At ordinary temperatures and in the absence of air dimethyl hydrazine is stable and

does not explode. Its thermostability is satisfactory but at elevated temperatures it decomposes, releasing heat and generating hot gaseous products, and explodes on overheating in a closed chamber. It is more stable and less explosive than HYDRAZINE and MONOMETHYL HYDRAZINE. Many structural materials are only slightly attacked by it. Extensively used in combination with NITRIC ACID ROCKET OXIDIZERS and with NITROGEN TETROXIDE forming self-igniting propellant. Also used with LOX (USSR). It is a component of AEROSENE-50 (USA).

DIRECTIVITY PATTERN of an antenna. A graph (usually in polar coordinates) representing the ability of the antenna to emit or receive radio waves in different directions. For an omni-antenna the polar directivity pattern is a circle, but for a directional antenna the curve will have a certain number



(*a*) Directivity pattern of omnidirectional antenna in horizontal plane; (*b*) Directivity pattern of parabolic antenna.
1—major lobe; *2*—parabolic mirror; *3*—minor lobes; *4*—angle characterizing lobe width of directivity pattern.

of lobes. Of these, the one having the greatest maximum is termed the major lobe, the others, the minor or side lobes. The latter are suppressed as much as possible to prevent the antenna from receiving noise from the directions these lobes correspond to. Polar directivity patterns are plotted as field intensity or as power intensity diagrams, using measurements taken at different points and at the same distance from the antenna. A parameter obtained from the directivity pattern for purposes of comparison is the lobe width, expressed through the angle subtended by two lines drawn from the origin to the points on the major lobe where the intensity is 0.707 time that of the lobe maximum.

DISSIPATION of atmosphere. Irretrievable loss of particles escaping from the outer part of a planet's atmosphere into space. Greatly depends on the velocity of particles in EXOSPHERE and, therefore, on temperature of atmosphere and mass of the particles. Hydrogen atoms are practically the only neutral particles to dissipate, dissipation taking place mainly in the most strongly heated noon region of the upper atmosphere, and also in the regions of strong heating during aurorae. Besides, in polar regions with open lines of force extending into the tail of the MAGNETOSPHERE, dissipation of ions and electrons is possible as well as on heating in aurorae and also under the action of electric fields along lines of force. In this case the possibility of dissipation of ions of different mass depends on their charge-to-mass ratio, as different from thermal dissipation (evaporation). The reverse process is accretion.

DISSOCIATION. The splitting of complex molecules into simpler ones or into atoms under the influence of high temperature and/or other factors; is usually associated with energy absorption. The dissociation of combustion products in a rocket engine lowers the temperature of gases. A certain part

of the dissociated molecules are recombined in the nozzle (see RECOMBINATION). Dissociation usually causes losses in specific impulse and is of importance in processes of hypersonic flow past spacecraft, e.g., during the flight of a RE-ENTRY BODY in the atmosphere when a sharp increase (up to several thou. °K) is observed in air temperature in PRESSURE SHOCKS and the boundary layer. In that event dissociation also leads to a drop in the temperature of air. Thus, in case of a spacecraft motion in atmosphere at FIRST COSMIC VELOCITY the impact temperature of the air would reach 18,000°K, were there no dissociation. However, due to dissociation it amounts to 6000—8000°K (depending on the degree of dissociation), only.

DISTURBANCES OF ORBIT. Deviations in the motions of celestial bodies (planets, their satellites, spacecraft, etc.) from trajectories precalculated according to the PROBLEM OF TWO BODIES, i.e., deviations from CONIC SECTIONS. Disturbances are due to the fact that a planet is attracted not only by the central body (the Sun), but by all the other planets as well. Disturbances in the motion of artificial Earth satellites are caused by the irregular shape of the Earth, air drag, attraction by the Moon and the Sun, etc. The calculation of disturbances of celestial bodies is one of the main tasks of CELESTIAL MECHANICS. Disturbances in the coordinates of celestial bodies as well as in their ORBITAL ELEMENTS can be calculated by various methods. (See also LONG-PERIOD DISTURBANCES, SECULAR DISTURBANCES, SECULAR-PERIODIC DISTURBANCES, SHORT-PERIOD DISTURBANCES).

DISTURBANCES OF FIRST ORDER. Disturbances proportional to the 1st order of the mass of the disturbing celestial body, to the 1st order of the oblateness of the Earth, to the 1st order of the atmospheric density, or, in general, to the 1st order of any parameter defining the disturbing force.

DISTURBED MOTION. The actual motion of a celestial body.

DISTURBING MOMENTS. Moments disturbing the prescribed angular position of a spacecraft imparted to it in the process of ORIENTATION or ANGULAR STABILIZATION. During the work of the rocket engine, the main source of disturbing moments is the deviation of the engine thrust from the precomputed direction; during atmospheric flight aerodynamic disturbing moments play an important role. In orientation systems in which the CONTROLLING MOMENTS are small, noticeable effect may be produced even by very weak disturbing moments, such as GRAVITATIONAL MOMENTS, moments of the forces of pressure of solar light, from meteorite impacts, moments from the interaction of the current-carrying circuits of spaceborne systems with the external magnetic field, etc. In designing precise orientation systems all sources of disturbing moments are reckoned with, and measures are taken to eliminate them as completely as possible.

DOCKING of spacecraft. See IN-ORBIT ASSEMBLY.

DOPPLER EFFECT. A change in the observed frequency of oscillation, occurring at motion of the source and/or the receiver of the waves. The frequency increases at their approach and diminishes when they recede. The extent of the shift depends on the velocity of the relative motion. This obstructs space communication as the resulting difference of several hundreds kc/s in the frequency of transmitted and received signals necessitates either a widening of the receiver passband or its programmed retuning. The Doppler effect

is utilized for measuring speed of motion, determining the orbits of spacecraft, and for radio navigation.

DOSING APPARATUS. A device for measuring the amount of rocket propellant loaded into the tank of a space vehicle. It consists of a primary device for measuring out the amount of the propellant and a secondary device for indicating the measured amount of propellant or signalling it to the system of automatic control. Dosing apparatuses are divided into volumetric and weighing. The former measure either the volume of the propellant loaded, by a system of level sensing in a calibrated container, or the volume flow rate, by a volumetric flowmeter which indicates the volume of the propellant passing through the measuring chamber per unit of time. Volumetric flowmeters include litre-meters with oval gears, disk litre-meters, litre-meters with an annular piston, etc. Other types are devices for measuring the velocity of the propellant flow in the pipeline, which, at a specified cross section of the pipe, indicates the volume flow rate. Such devices include turbine and supersonic flowmeters. Weighing apparatuses measure the weight of the propellant filled; they may be of the balance type, or be provided with strain gauges or hydraulic dynamometers, or of other types.

DOUBLE-BASE PROPELLANT. See HOMOGENEOUS SOLID PROPELLANT.

DRAG. An aerodynamic force applied to a spacecraft moving through the atmosphere and directed in opposition to the velocity vector of the spacecraft. The drag can be controlled to a certain degree by the employment of rotary vanes and other braking devices used for CONTROLLED RE-ENTRY.

DRAINAGE. Removal of air mixed with propellant vapours through valves and pipes from the launch vehicle propellant tanks during propellant loading; release of excess gas pressure from the propellant storage containers; pouring of the excess of a propellant component out of the launch vehicle tank into a special container; discharge of propellants from the fueling lines after fueling; venting of gases from receivers and cylinders.

DRAIN SAFETY VALVE. See PROPELLANT LOADING FITTINGS.

DRAIN VALVE. See PROPELLANT LOADING FITTINGS.

DRIFT of a gyroscope (or of a GYRO-STABILIZED PLATFORM). The main quality factor of a gyro that determines the rate of angular displacement of the gyroscope axis from its initial direction. This drift is due to inaccurate balancing of the gyro, friction in the gimbal bearings, parasitic torques of the angular-position pickups and current-carrying leads, and other disturbances that cannot be completely eliminated for technical reasons. Highly accurate gyros have a drift rate of the order of or less than 0.1 to 0.01 angular degrees per hour.

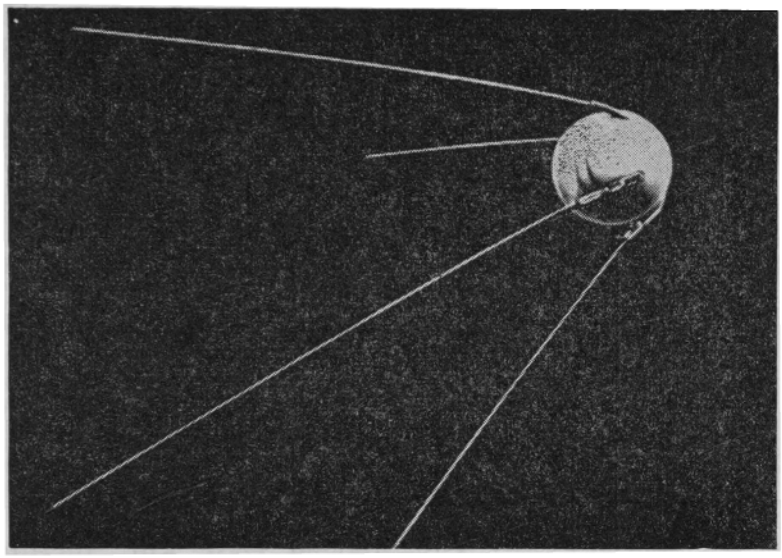
DYNAMIC COMPRESSION. A quantity equal to $(C-A)/C$, where A and C are the principal central moments of inertia of a celestial body. Dynamic compression characterizes the oblateness of a celestial body relative to the plane of the equator.

DYSON'S SPHERE. Hypothetical artificial material sphere created around a star by a highly-developed civilization with the object of a maximum utilization of the star's radiant energy. The sphere is created by spreading the matter of a massive planet as a thin-walled shell enveloping the star on all sides at a certain distance from it. If the hypothesis of the existence of such

Dyson's sphere

spheres, by F. Dyson (USA), is true, the most probable habitat of highly-developed extraterrestrial civilizations will not be the planets of visible stars, but dark objects with a radius of the order of 1 A.U. and a temperature of 200—300°K. They must emit at wavelengths of about 10 μ in the IR region because the star's visible radiation is completely intercepted by Dyson's sphere and, according to equilibrium conditions, is re-emitted in the thermal region. Dyson says that the need for creating such a sphere, i.e., for using power comparable to that of the Sun, may arise in the case of terrestrial civilization as soon as in 3000 years, assuming a modest increase in power consumption at the rate of 1% a year. Dyson does not consider either practical ways for creating such a sphere or its stability upon rotation. A definitely dynamically stable "shell" version of Dyson's sphere has been suggested by the Soviet scientist G. I. Pokrovsky.

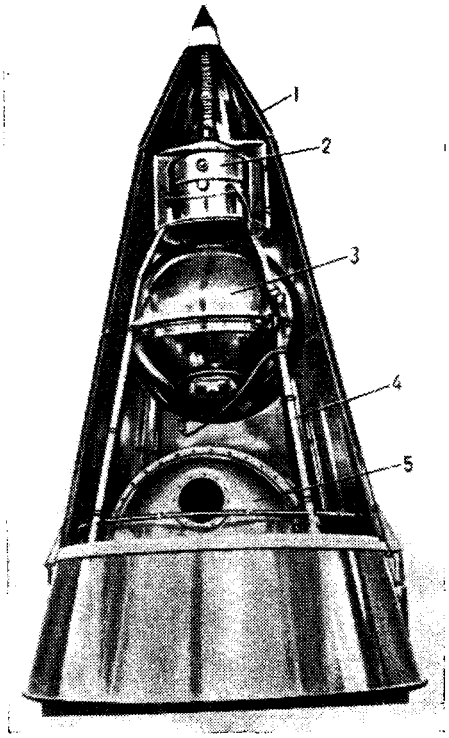
EARLY SOVIET EARTH SATELLITES. *Sputnik-1.* The world's first Soviet artificial Earth satellite went into orbit on October 4, 1957. It weighed 83.6 kg, had the form of a sphere 580 mm in dia, and carried 4 rod antennas 2.4—2.9 m long. The instruments and electric power sources were housed in a sealed capsule and included transmitters operated at 20.005 and 40.002 Mc/s (wave-lengths 15 and 7.5 m) to send series of pulsed signals of 0.3 s mean duration. The power sources permitted operation of the equipment for three



First Soviet Earth satellite *Sputnik-1*

weeks. The initial orbit parameters were: perigee 228 km, apogee 947 km, inclination 65.1°. The satellite lived as a celestial body for 92 days, and entered the dense atmosphere layers on January 4, 1958. *Sputnik-1* for the first time in history made it possible to determine the density of the upper layers of the atmosphere (from the changes produced in its orbit), to obtain data on the propagation of radio signals in the ionosphere, to check theoretical calculations and design concepts (to improve the techniques of injection into orbit, the temperature conditions, etc.).

Sputnik-2. Second Soviet Earth satellite which proved to be the world's 2nd unmanned spacecraft, and the 1st BIOLOGICAL SATELLITE to go into outer space. It went into orbit on November 3, 1957, and comprised the last stage of the launch vehicle. This last stage housed several compartments accommodating scientific and measuring instruments and a sealed cabin containing the experimental dog Laika. All the instruments, the dog, and the power sources weighed 508.3 kg. The satellite equipment included two radio transmitters, a telemetry system, a programming unit, scientific instruments for obtaining data on Sun radiation and cosmic rays, and a cabin regeneration and temperature control system for life support of the animal. The initial orbit parameters were: perigee 225 km, apogee 1671 km, inclination 65.1°. The *Sputnik-2* lived in orbit till April 14, 1958. This satellite



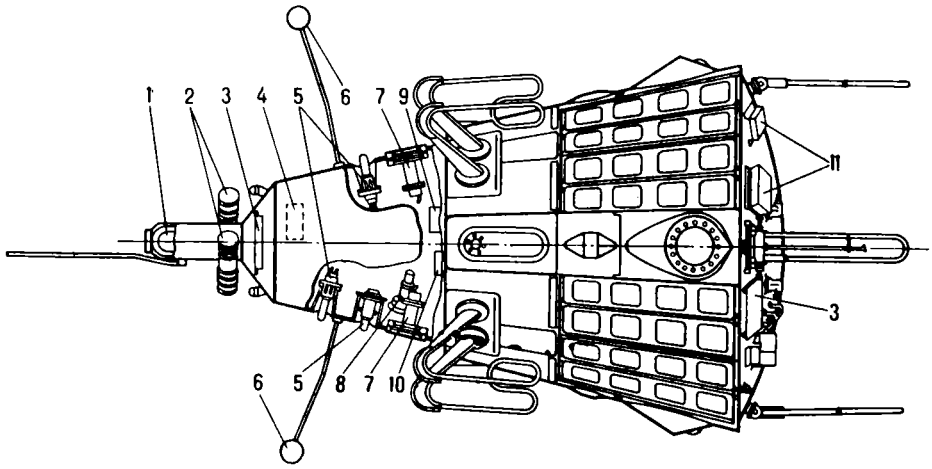
provided the scientists with the first data on the behavior of a living organism during flight in outer space.

Sputnik-3. Third Soviet Earth satellite and the first automatic scientific laboratory to go into space. It was launched on May 15, 1958, and carried 12 different scientific instruments, a multi-channel telemetry system incorporating a memory unit, radio equipment for precise orbital measurement, a *Mayak* radio transmitter, a temperature control system, a program control timer, and other equipment. This satellite weighed 1327 kg, was 3.57 m long, and carried 968 kg of scientific and measuring equipment. The initial orbit

Arrangement of equipment of second Soviet Earth satellite *Sputnik-2.*

1—conical fairing discarded after satellite's injection into orbit; *2*—instrument for measuring UV and X-ray emissions of the Sun; *3*—spherical capsule carrying the instruments and radio transmitters; *4*—frame supporting the equipment; *5*—sealed compartment containing the experimental animal.

parameters were: perigee 226 km, apogee 1881 km, inclination 65.1°. Flight on orbit continued up to April 6, 1960. A large program of research



Features of third Soviet Earth satellite *Sputnik-3.*

1—magnetometer; *2*—photomultipliers for registering corpuscular radiation of the Sun; *3*—solar cells; *4*—instrument for registering photons in cosmic rays; *5*—magnetic and ionization-type pressure gauges; *6*—ion traps; *7*—electrostatic flux meters; *8*—mass spectrometer tube; *9*—instrument for recording heavy nuclei in cosmic rays; *10*—instrument for measuring primary cosmic ray radiation intensity; *11*—sensors for registering micrometeor encounters.

Housed within the satellite enclosure are electronic units of scientific instruments, radio measuring equipment, timer, and chemical batteries.

on near space was realized with this satellite (pressure in and composition of the upper atmosphere, concentration of charged particles, cosmic rays, magnetic and electrostatic fields, meteoric particles, etc.). One result was detection of the outer radiation belts of the Earth.

EARTH. The third planet of the solar system in distance from the Sun. In its revolutions around the Sun Earth follows an elliptical orbit with a mean velocity of 29.76 km/sec. The orbit has an eccentricity of 0.0167. At the beginning of July the Earth is as its greatest distance from the Sun at aphelion ($152 \cdot 10^6$ km) which it passes with a velocity of 29.27 km/s; at the beginning of January it passes its nearest point to the Sun—the perihelion ($147 \cdot 10^6$ km)—with a velocity of 30.27 km/s. The orbital period of revolution around the Sun is equal to 365.2564 mean solar days. The Earth rotates on its axis inclined to the ecliptic at an angle of 66°33′15·2″ (for 1950) in 23 h 56 min 4.0905 s of mean solar time. The angular velocity (ω) is $7.29213 \times \times 10^{-5}$ radian/s. The Earth's mass is $5.98 \cdot 10^{27}$ g; the mean density is 5.517 g/cm^3. The acceleration of gravity at the equator is 978.049 cm/s^2, at the poles it is 983.235 cm/s^2. The first cosmic velocity at an altitude of 200 km is 7.79 km/s; the second cosmic velocity at the surface is 11.19 km/s. Due to the diurnal rotation of the Earth all points on its surface have a certain linear velocity that is taken into account in launching space vehicles. The Earth's natural satellite, the MOON, is one of the largest satellites in the solar system. The Earth's axis of rotation maintains a practically constant orientation and this causes the change of seasons. Under the disturbing influence of other planets the inclination of the Earth's axis to the ecliptic increases by 46.8″ per century.

The Earth's figure is an oblate sphere resembling an ellipsoid of rotation. Its parameters established by F. A. Krassovsky in 1940 are as follows: oblateness 1 : 298.3; the semi-minor axis coinciding with the axis of rotation is 6356.86 km; the semi-major axis lying in the equatorial plane, is 6378.24 km; the surface area is $5.10 \cdot 10^8$ km^2; the volume is $1.083 \cdot 10^{12}$ km^3. From observations of artificial Earth satellites it follows that the equatorial radius is 6375.75 km; the North polar radius is 6355.39 km; the South polar radius is 6355.36 km, and the oblateness is 1 : 298.2. The true figure of the Earth does not correspond to any ideal geometrical figure and is quite irregular. Generally it is considered a geoid (the surface of a geoid is normal to the direction of gravity in every point) depending on the Earth interior structure as well as on the distribution of mass above sea level. The oblateness of the Earth and the irregular distribution of mass are the main reasons why the Earth's axis of rotation gradually wobbles so as to describe a circular cone (with an axis normal to the ecliptic) under the forces of attraction of the Moon and the Sun. This results in an eastward movement of the equinoctial points along the ecliptic at the rate of 50.3″ per year. This movement is also affected by the gravity attraction of other planets which causes the angle between the ecliptic and the equator to decrease by about 0.5″ per year. The period of this precessional rotation of the Earth's axis is equal to 360° : 50.3″, or approximately 26,000 years. The nutational oscillation of the Earth's axis caused by the change of position of the lunar orbit plane relative to the ecliptic, has a period of 18.6 years corresponding to the period of revolution of

the lunar nodes. The Earth's axis also changes its position in the globe. The drift of the poles and the consequent changes in latitudes have a periodic character. 2 main periods are distinguished: 14 months for elastic deformations in the Earth's body, and 12 months for seasonal redistribution of atmospheric masses, precipitation, etc.

The main features of the Earth's surface are continents and oceans. *Terra firma* occupies 29% of the surface (149 million km^2) and water covers 71% (361 million km^2). The mean difference in levels between the continents and the oceans is about 4.5 km, the maximum being nearly 20 km (Mt. Everest—the Marianas trough).

Geophysics, geology and geochemistry make a study of the structure of the Earth's interior. Its upper layer (the crust) has a thickness of about 40 km (usually less beneath the floor of the oceans); its mean density is about 3 g/cm^3. The age of the Earth's crust deduced from radioactive isotopes and products of their decay is $4.5 \cdot 10^9$ years. Below the crust, to a depth of about 2900 km, lies the mantle consisting of concentric layers with corresponding densities of 3.3—3.6; 3.6—4.7 and 4.7—5.7 g/cm^3, increasing with depth. Under the mantle lies the core. The density of the core's layer at depths of 2900—4900 km is 9.4—11.5 g/cm^3; it is partly in a melted state. The density of the central part of the core is 14.5—18 g/cm^3 and the temperature in the Earth's centre is probably about 10,000°K. The Earth is surrounded by a dense atmosphere weighing about $5 \cdot 10^{15}$ t. It consists of a mixture of gases that occupy the following volumes at sea level: 78.08% nitrogen; 20.95% oxygen; 0.93% argon; 0.03% carbon dioxide. All the rest of the components including hydrogen, helium, xenon, krypton, methane, neon, etc. constitute only a few millionths of 1%. Of great importance are such volumetrically variable components as water vapour and ozone.

The power of solar energy incident to the Earth is $1.7 \cdot 10^{24}$ erg/s. About 55% of this energy is absorbed by the atmosphere and the surface and later, after a series of transformations, is re-radiated into outer space in the IR region of the spectrum. Nearly 45% of the solar energy reaching the Earth is reflected back. The atmosphere selectively absorbs UV and X-rays that present a hazard to life on Earth. Besides, the IR radiation is effectively absorbed by water vapour, carbon dioxide and ozone. This phenomenon, called the greenhouse effect, is of great importance since it increases the Earth's mean temperature by 40°K. This makes life on Earth possible. Solar radiation in the region of 2000—3000 Å is absorbed by the ozone layer and causes photochemical dissociation of ozone. The heat released during this reaction raises the temperature of the atmosphere at an altitude of 25—50 km. At a level of 80—110 km molecules of oxygen dissociate, this reaction is also accompanied by heat release. At altitudes of 200—300 km short-wave radiation of 900 Å and shorter ionizes atomic oxygen, etc. Thus solar radiation produces a complex vertical structure in the atmosphere, temperature inversions, successive layers such as the troposphere, stratosphere, mesosphere and thermosphere, redistribution of chemical composition, layers of the ionosphere, etc.

Earth satellites launched in the USSR and USA have proved unique instruments for exploring the upper atmosphere.

The Earth is surrounded by a magnetic field. The North magnetic pole drifts at a rate of 5—6 km per year, while the drift of the South pole is a little more rapid. The Earth's magnetic field undergoes secular and sporadic changes called magnetic storms. The latter are responsible for disturbances in the magnetic field and in the propagation of radio waves, and cause aurorae in high latitudes. Magnetic storms are produced by solar flares; their hard radiation increases ionization in the ionosphere and produces strong currents. The Earth's magnetic field has a great influence on electrically charged particles moving in outer space, such as cosmic rays and corpuscular streams ejected by the Sun. Part of them, with energies of over 10^9 eV, penetrate the Earth's magnetic field in equatorial regions and produce a stream of secondary cosmic rays by interaction with atmospheric atoms. According to experiments carried out in open space, a great number of high-energy electrons and protons are trapped in the magnetic field. Their energy and concentration vary with distance from the Earth and with geomagnetic latitude. The Earth is bounded by an extensive radiation belt where the trapped particles move. The inner zone of the belt is limited by geomagnetic latitudes $\pm 45°$ and altitudes of 500 to 5000 km. The outer zone lies at a distance of 1 to 5 Earth radii. The boundaries of and particle energies in the radiation zones vary with time. Thus, during solar flares radiation level increases many thousand times as compared to the quiet level. It is necessary to take all these factors into account when planning a space flight in order to choose an optimal trajectory.

EARTH ALBEDO RADIATION. Solar radiation reflected and scattered by atmosphere and clouds into outer space. Is measured by means of ACTINOMETRIC INSTRUMENTATION of meteorological satellites. Variations of the Earth albedo radiation in space and time are chiefly due to variability of cloudiness and non-homogeneity of the underlying surface. With cloudless atmosphere the Earth albedo radiation is minimum in areas of bodies of water (when the Sun is not too low) and in areas with a vegetative cover, it increases in desert regions and becomes maximum in the zone of the snow cover. The Earth albedo radiation exhibits diurnal and annual variations and also depends on geographical latitude, its average value in the Northern Hemisphere is 0.176 cal/cm^2/min; occasionally it varies within the range of approx. 0.1—1.8 cal/cm^2/min.

EARTH NOISE. Irregularly varying currents appearing in the input circuits of a radio receiver due to the Earth's heat radiation. Earth noise appears in the ultrashort waveband and increases in proportion to the sensitivity and frequency passband width of the receiver. The Earth NOISE TEMPERATURE at the input of the ground station receiver usually equals 20—60°K and can be reduced to a level of 5—15°K by employing an antenna of suitable design. Earth noise prohibits the use of highly sensitive receivers on Earth satellites, since the useful signals and Earth noise are received from the same direction.

EARTH RADIATION. Thermal radiation of the Earth's surface, clouds and atmosphere going out into space; is measured by means of IR and ACTINOMETRIC INSTRUMENTATION of meteorological satellites. Variations of the Earth radiation in space and time are due primarily to varying nebu-

losity and underlying surface. The Earth radiation is maximum over deserts; appearance of clouds results, as a rule, in diminishing of Earth radiation, which becomes minimum in regions of dense nebulosity with a high upper boundary. The Earth radiation displays diurnal and annual variations and also changes substantially with geographic latitude. The average annual radiation amounts to 0.324 cal/cm²/min; in some cases it varies within the range of 0.1 to 0.5 cal/cm²/min.

EARTH STATION. According to the definition adopted by the Extraordinary Administrative Conference on Radio Communication (Geneva, 1963), this is a space communication station located either on the surface of the Earth (including seaborne stations) or on board an aircraft. Earth stations are used for radio communication with or via a spacecraft. The term "Earth station" implies that it differs from ground stations that serve for maintaining ground radio communication without the use of spacecraft.

EARTH TRACKING STATION. A set of transmitting and receiving radio equipment used for measuring and determining the parameters of spacecraft trajectories. As a rule, earth tracking stations maintain communication with spacecraft for controlling their flight by commands and receiving telemetry data. Earth tracking stations are linked by means of ground communication lines with the integrated mission control centre that processes the information received from the spacecraft and provides adequate control of the spacecraft and SPACE SYSTEMS.

EASTERN TEST RANGE. (Prior to 1965, Atlantic Missile Range). The largest space centre in the USA; its launch complexes are built at Cape Kennedy in an area with the centre at 20°30′ N.L. and 80°50′ W.L. The space centre occupies an area of 400 km² and its 20,000-km range extends over the Atlantic and Indian Oceans. Located on the range are about 15 ground tracking stations equipped with optical, telemetry and radar instruments. In addition, rockets are tracked by dozens of ships and aircraft and by more than a hundred of ground observation posts. The system of tracking stations of the Eastern Test Range allows the launching of rockets at an azimuth of from 44° to 110° and injection of Earth satellites into orbits with an inclination angle from 28.5° to 52.4° with an Eastern direction of the launch. Functioning of all the systems and services of the Eastern Test Range is coordinated by the range control centre. The control centre building accommodates 7 signal panels (including one 2.4·2.4 m in size) showing the actual and pre-estimated parameters of the rocket trajectory and the expected impact point, as well as 34 TV screens, 137 control panels and 800 display panels for checking the operation of the tracking stations. All this information display equipment is controlled by some 100 operators. A majority of space research programmes in the USA make use of the launch complexes of the Eastern Test Range.

The launch complexes on Cape Kennedy blast off various types of space bodies by means of *Atlas*, *Titan*, *Saturn* and other launch vehicles. Realization of important American space research programmes such as *Mercury* and *Gemini*, was based on the Eastern Test Range. Launch complex 39, erected at the Eastern Test Range to accommodate *Saturn-5* launch vehicles, is designed for sending astronauts to the Moon in accordance with the *Apollo*

programme. In addition to space research, the Eastern Test Range is widely used for testing the American military missiles.

The Range (including service stations) employs about 20,000 men. More than 200 flight tests and a few thousand ground tests of rockets are carried out yearly in the space centre. The operating costs of the range exceed $100,000,000 a year.

ECLIPTIC. The great circle on the celestial sphere that represents the apparent annual path of the Sun.

ECOLOGICAL SYSTEM. An interconnected biochemical complex consisting of elements whose interaction results in a closed cycle of materials. Any ecological system, irrespective of its dimensions and complexity, consists of the following principal elements: producing organisms that create organic compounds out of inorganic substances; consumer organisms that feed on the producing organisms; decomposer organisms that decompose organic materials contained in the waste of the first two groups of organisms and, finally, abiotic constituents of the system, which provide for circulation of substances between all system members. In space biology and medicine the term "ecological system" implies the artificial BIOTECHNICAL SYSTEM on board a spaceship, in which circulation of substances, i.e., regeneration of air, water and food and MINERALIZATION of biological waste, takes place.

ECOLOGY. A branch of biology that studies the relations of organisms to their environment, the organisms studied being all the plants and animals of a certain environment. With respect to space flights, ecology studies the interrelations of the members of a spaceship biocomplex and the environment in the sealed cabin.

EFFECTIVE EXHAUST VELOCITY. An arbitrary index of the exhaust velocity obtained by dividing the value of the rocket engine thrust by the mass of propellant consumed per second.

EFFECTIVE HEIGHT. See IONOSONDE.

EFFECTIVENESS OF PROPELLANT (relative). The characteristic of a propellant that is determined by the ultimate result of its utilization in the rocket, i.e., the payload carried by the rocket in a given flight route. It is determined by comparing the results of utilization of different propellants under similar conditions on a particular rocket, obtained by theoretical calculations confirmed experimentally. Sometimes, for preliminary evaluation of new propellants or when choosing an appropriate propellant, the determination of effectiveness is reduced to calculating the burnout velocity of the rocket or the mass of the payload accelerated to a specified burnout velocity, by a method that takes into account, of all the performance parameters of the propellant, only its specific impulse and density. Effectiveness depends likewise on the conditions under which the propellant is used. For the lower stages of the rocket the specific impulse is of less significance than for the upper stages, while the density is more important for the lower stages.

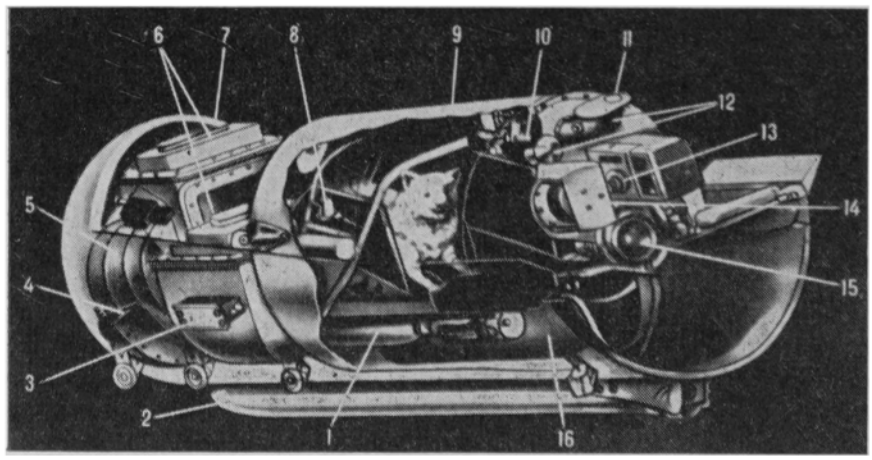
EFFICIENCY of rocket engine. The value characterising the degree of perfection and effectiveness of a rocket engine. For instance, overall efficiency, or the ratio of the kinetic energy of the rocket efflux to the potential energy of

the propellant burnt, is determined by specific efficiencies (thermal, relative, etc.); propulsion efficiency determines the transition of the kinetic energy of efflux into the useful work of propulsing the vehicle, etc. The thermal and overall efficiencies of the rocket engine are higher than those of other thermal engines. Instead of efficiency characterising the perfection and effectiveness of the rocket engine as a thermal machine, used in rocket engineering are other values, e.g., a system of ratios, such as thrust coefficient, specific impulse, completeness-of-pressure coefficient, and nozzle efficiency.

EISELE, Donn (born 1930, Columbus, Ohio). US astronaut, USAF major. Graduate of US Naval Academy (1952) and a school for test pilots. Received his scientific degree from the Air Force Institute of Technology in Dayton. Pilot for testing special weapons at Kirtland Air Force Base. Joined the NASA group of astronauts in 1963. Was a member of the crew of the *Apollo-7* (together with W. Cunningham and W. Schirra) which made 163 orbits round the Earth (October 11—22, 1968).

EJECTION. Emergency abandoning the vehicle resorted to in aerospace practice. The pilot is ejected together with his seat usually by solid-propellant rockets (see EMERGENCY ESCAPE SYSTEM). In the *Vostok* spaceship ejection was part of the general system for landing the crew. Ejection is accompanied by shock acceleration.

EJECTION CAPSULE. A spaceship capsule designed to accommodate animals under test. Some Soviet satellite-spaceships were provided with such capsules which were prototypes of spacemen's ejection seat. The capsule contained a cabin for animals (dogs) with automatic feeding equipment, sanitation device and ventilation system; ejection and parachute systems; homing radio beacons and other equipment. The ejection of capsule was performed

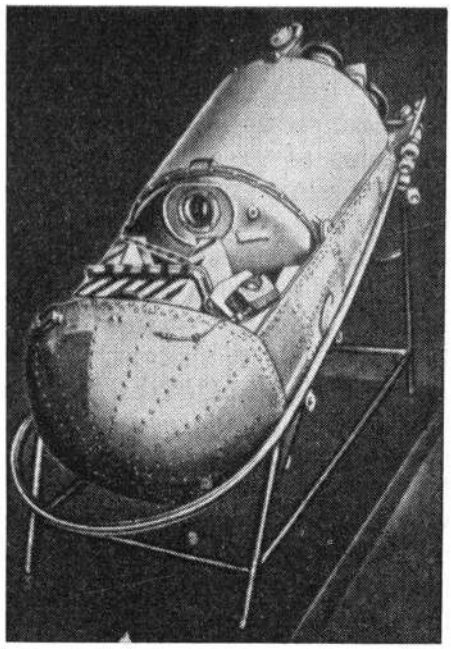


Sealed cabin for animal accommodation in ejection container of *Sputnik-2*

1—cylinder of air-supply system; *2*—ejection cartridge unit; *3*—direction finder unit; *4*—storage battery; *6*—instrument compartment; *7*—container body; *8*—dog movement sensor; *9*—air-tight cabin for animal; *10*—microphone; *11*—antenna of direction finder; *12*—inhalation and exhalation valves; *13*—TV camera; *14*—mirror; *15*—ventilation unit; *16*—automatic device for combination feeding.

during the spaceship re-entry at an altitude of about 7 km; its landing speed was 6—8 m/s.

EJECTION SEAT. A spaceman's seat supplied with means for ejection from the capsule and subsequent parachute descent. This method of landing from altitudes of several km above the Earth was provided for certain spaceships (see VOSTOK). The ejection seat also provides a means of escape for the spaceman in the event of an emergency during take-off or powered flight. An ejection seat incorporates several systems and devices such as: the ejection cartridge, parachute system, oxygen supply and pressurized suit ventilating system, radio receiver and transmitter, supply of food and necessities that may be needed by spacemen after landing, etc. The ejection seat has a bearing surface usually padded with soft plastic, whose contour matches the shapes of the spaceman's body.



Ejection container.

Ejection seat (on support).

Elastic vibration

ELASTIC VIBRATION. Longitudinal and transverse vibration of the launch vehicle body which depends on the stiffness of its structural elements. Transverse vibration takes the form of a slight periodic deformation (bending) of the launch vehicle longitudinal axis and is a feature of high-power launch vehicles of great elongation; longitudinal vibration causes slight periodic compression and elongation of the rocket body along its axis. These vibrations increase the load applied to the structural elements and are taken into account in structural stress analysis. Besides, transverse vibration may influence the operation of the automatic device for angular stabilization of the launch vehicle, while the longitudinal vibration affects the operation of propellant-feed system of the rocket engine.

ELECTRICAL CONNECTOR. A multi-circuit plug connector used for joining cable lines of spacecraft, launch vehicles and ground equipment. Electrical connectors that are separated prior to vehicle launching at the command from the checkout and launching equipment are called separation connectors, whereas those that are separated at take-off of the launch vehicle are called umbilical connectors. Several tens and even hundreds of cables may be brought up to the launch vehicle and, therefore, the connectors are grouped together into a few separate blocks. The ground part of the connector is connected to the rocket-borne part by hand or by a special mechanism. Guide pins entering their reciprocal holes of the receiving part of the connector are provided for facilitating the alignment and connection.

ELECTRICAL ROCKET. A rocket powered by an electrical engine capable of developing very high exhaust velocities at low values of thrust (smaller than the rocket weight by a factor of several thousand). Owing to this, an electric rocket can only start after it has been imparted a cosmic velocity, e.g., from a satellite orbit. For this, it must be launched into the orbit by a chemical or nuclear rocket developing high thrust (greater than the weight of the space vehicle). Operation of an electric rocket engine may continue for several months. The trajectory of the rocket in the field of gravitation of a planet in this case is a slowly increasing spiral. These types of rockets are still in the development stage. They are prospective in that they offer greater payload capacity than obtainable with other types of rocket engines.

ELECTRICAL ROCKET ENGINE. A rocket engine in which the working fluid is accelerated to discharge velocities (such velocities are unattainable in conventional rocket engines using the chemical energy of propellant) by means of electric energy. Electrical rocket engines have a very high specific impulse. The comparatively big weight of the electric power plant (mainly with a nuclear reactor) determines the small thrust-to-weight ratio of spacecraft. That is why electrical rocket engines can be used only on the upper stages of space rockets after they had already been imparted the orbital velocity and when minor accelerations of the order of 10^{-3} to 10^{-4} g are feasible to increase the rocket speed. Electrical rocket engines have to operate for as long as several months to impart the rocket the escape velocity. Experimental electrical rocket engines have been designed: electrothermal, electromagnetic, electrostatic (ion). The USSR (on the *Zond* automatic interplanetary stations and *Cosmos* satellites) and the USA have flight-tested electrical rocket engines.

ELECTRIC IGNITION. Propellant ignition in a rocket engine by means of an electric plug (spark or incandescent). It is used in small rocket engines or for ignition in the firing device of the fuel-oxidizer mixture (gaseous, liquid or solid) creating a flame which ignites the main propellant in the rocket engine.

ELECTRIC JACK. An electrically driven screw jack used in launchers, erectors, transport facilities and other launching equipment. This jack can be easily introduced into the system of automatic and remote control.

ELECTRIC POWER SUPPLY of a space centre. The electric supply services installed to receive or generate, distribute and feed electric power to all the facilities and equipment of the space centre. Certain units of launch complexes for greater reliability, besides the imported power, require standby supply from self-contained diesel or petrol power plants. The power circuit of such a launch complex is set up for automatic change-over from regular to standby supply and vice versa, i.e., supply is taken in through two cables so that the failure of any one source can be met by switching over to the healthy source. Each launch complex or maintenance area has a power supply circuit that comprises a central distributing station, transformer substations of the main facilities, and a system of remote control of the power distribution circuit. From the transformer substations, a series of 380/220 V, 50-cycle cables bring the power up to the local switch-boards. The latter supply the individual units.

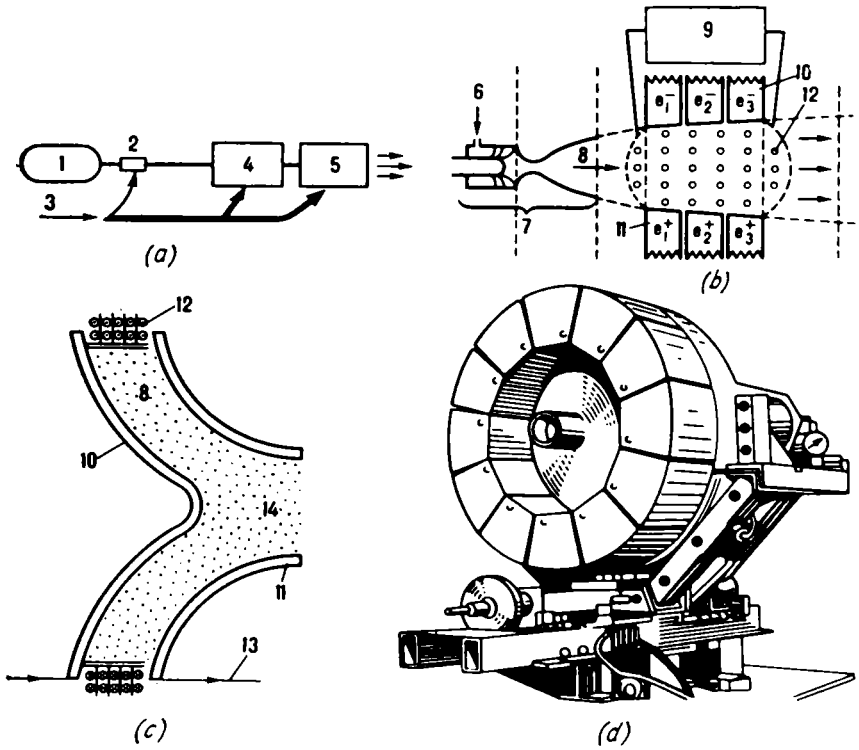
ELECTROCHEMICAL POWER SOURCES. Sources of electric energy in spacecraft power systems. These sources convert chemical energy into electric energy by an electrochemical reaction, and take the form of batteries of different types of secondary cells (silver-zinc, nickel-cadmium), primary (galvanic) cells (e.g., mercury cells), and FUEL CELLS. For short duration space flights, storage batteries charged prior to launching are used, but for prolonged missions it is necessary to carry buffer storage batteries which are periodically recharged by some space-borne primary source of electric energy, such as solar cells. This permits the use of the buffer at periods of greater demand, as occurs when a session of radio transmitter operation must be carried out, and to supply power when the solar cells are inoperative (during passage in the shadow of the Earth). Modern storage batteries reach watthour capacities of 100 Wh per kg of weight, which is much less than that of fuel cells.

ELECTRODIALYSIS. A physical method used in spaceship LSS for purification of colloid solutions or suspensions from residual electrolytes by application of electric field. The method consists in withdrawing ionized particles contained in water through semi-permeable membranes made of thin films of ion exchange resins. The cations migrate to the anode, while anions migrate to the cathode. Power consumption by the electrodialysis method is low and does not depend on the GRAVITATIONAL FIELD of Earth which permits this method to be used in systems of physico-chemical WATER REGENERATION for preliminary processing of liquid biological wastes to remove salts and other ionized compounds. After electrodialysis the water thus obtained is subjected to additional processing to remove urea, micro-organisms and other organic non-ionized compounds.

Electro-magnetic actuators

ELECTROMAGNETIC ACTUATORS of systems of spacecraft orientation. Current-carrying circuits, electromagnets and permanent magnets that produce control torques due to the interaction of their magnetic fields with the external magnetic field surrounding the spacecraft. These elements are effective only at use on spacecraft moving in the vicinity of the Earth or other planets possessing a sufficiently strong magnetic field. In comparison with orientation rocket motors, electromagnetic actuators have the advantage that their operation does not involve the consumption of the spaceborne WORKING FLUID.

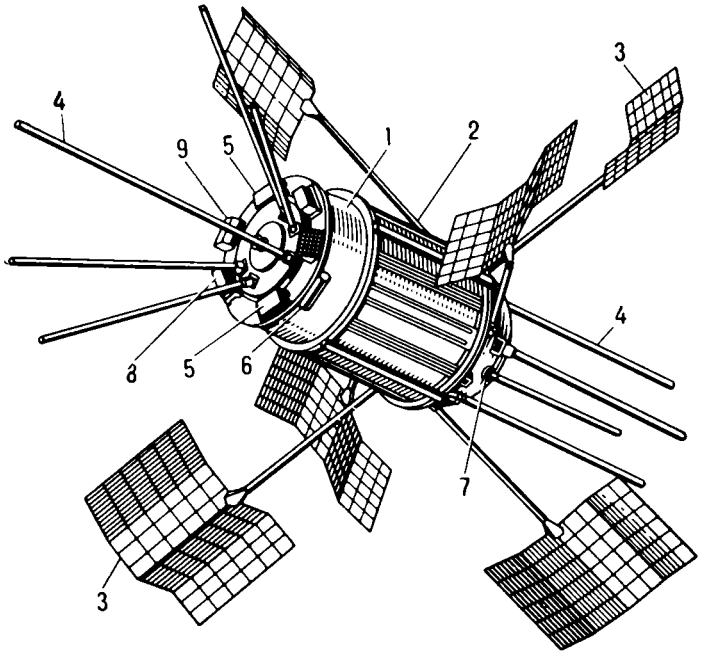
ELECTROMAGNETIC ROCKET ENGINE (plasma or magnetohydrodynamic). An electrical rocket engine in which the working fluid is in the plasma phase



Electromagnetic rocket engine: (*a*) schematic diagram; (*b*) diagram of engine with crossover electric and magnetic fields; (*c*), (*d*) diagram and appearance of pinch engine, USA (12 capacitors arranged around the nozzle discharge to produce the pinch effect in plasma, i. e., the effect of plasma contraction under the influence of magnetic field; the engine creates a thrust of about 50 g at jet velocities of 10 to 70 km/s).

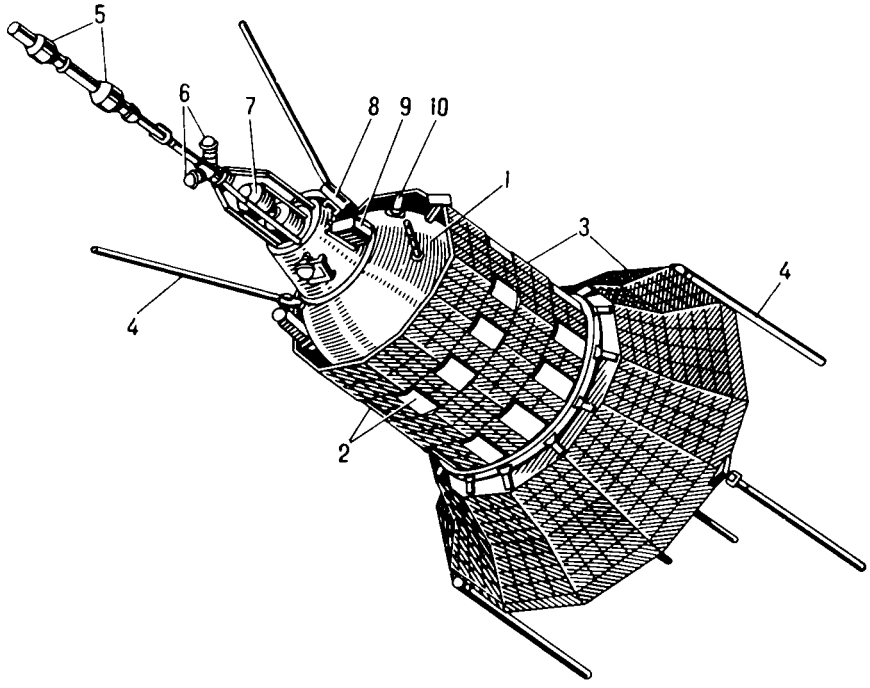
1—working fluid; *2*—pump; *3*—electric power supply; *4*—plasma generator; *5*—plasma accelerator; *6*—working fluid inlet; *7*—plasma arc generator; *8*—plasma jet; *9*—effective zone of magnetic field; *10*, *11*—electrodes; *12*—magnetic lines of force; *13*—capacitor current; *14*—nozzle.

and is accelerated by means of an electromagnetic field. A very high exhaust velocity is possible (hundreds of km/s). The engine is under development. It was first used practically in the attitude control system of the Soviet auto-



Electron-1 satellite.

1—sealed body; *2*—louvres of temperature control system; *3*—solar cells; *4*—antennas; *5*—micrometeorite detectors; *6*—instrument for recording corpuscular emission; *7*—mass-spectrometer; *8*—proton detector; *9*—instrument for investigation of energy spectrum of electrons in radiation belt.



Electron-2 satellite.

1—sealed body; *2*—louvres of temperature control system; *3*—solar cell batteries; *4*—antennas; *5*—magnetometers; *6*—solar sensors; *7*—spheric analyzer for investigation of energy spectrum of low-energy particles; *8*—instruments for investigation of chemical composition of cosmic rays; *9*—instrument for investigation of energy spectrum of electrons in radiation belt; *10*—mas-spectrometer.

matic station *Zond-2* launched in the direction of Mars on November 30, 1964.

ELECTRON. The name of systems comprising 2 Soviet SCIENTIFIC SATELLITES placed into different orbits by one launch vehicle for simultaneous investigation of external and internal zones of the Earth radiation belt. The 1st system of this series (*Electron-1* and *Electron-2*) was launched in the USSR on January 30, 1964, the 2nd (*Electron-3* and *Electron-4*), on July 11, 1964. *Electron-1* and *Electron-3* were orbiting at an apogee altitude of 7000 km and perigee altitude of 400 km with the task to study the internal zone of the radiation belt. The satellites were separated from the launch vehicle while the engine of the last stage was operating. *Electron-2* and *Electron-4* were injected into highly elongated orbit with apogees at 68,000 and 66,000 km, respectively, and perigee of 460 km. They investigated the external zone of the Earth radiation belt and the outer space beyond the belt. *Electron-1* and *Electron-3* had a weight of 350 kg, they were 0.75 m in dia and 1.3 m long. *Electron-2* and *Electron-4* weighed 445 kg and had a dia of 1.8 m and a height of 2.4 m. The *Electron* research systems enabled one to obtain a rich information on the radiation belt and the magnetic field of the Earth, which is necessary to ensure the radiation protection in manned flights of space vehicles, and to discover some new physical phenomena in the near-Earth space.

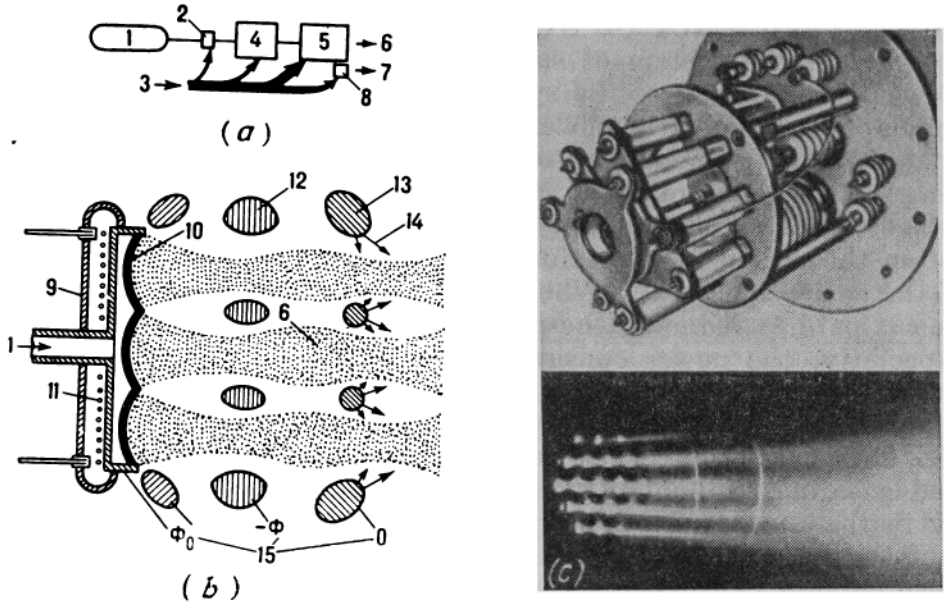
ELECTROSTATIC ROCKET ENGINE (ion, colloidal). An electrical rocket engine in which the working fluid, usually alkali metals (cesium, rubidium) or other elements (mercury, argon, etc.), is ionized, and the resulting ions are accelerated in an intense electrostatic field to velocities of tens and hundreds of km/sec. To make the jet efflux neutral, electrostatic rocket engines have a device for neutralising the beam of ions by electrons. The engine is in the stage of experimental development. First tests of such an engine in orbital flight were performed on the *Voskhod* spaceship in 1964. Ser Fig., p. 125.

ELECTROTHERMAL ROCKET ENGINE. An electrical rocket engine in which the working fluid is heated to a high temperature by an electric arc, resistance heating or other methods (see ARC ROCKET ENGINE). Further, the heated working fluid, usually gases fo low molecular weight (helium, hydrogen, etc.), expands in the nozzle. The exhaust velocity may reach 20 km/s. It is in the stage of experimental development.

ELEVATION ANGLE. A coordinate in he horizontal system of CELESTIAL COORDINATES used sometimes for locatintg man-made bodies in outer space. The same as ALTITUDE.

ELLIPSE. A closed 2nd-degree curve; the locus of points for which the sum of the distances from 2 given points (foci) is a constant value. Ellipse is one of the possible shapes an orbit can obtain in the gravity field of an attracting centre. In this case the attracting centre is located in one of the foci of the elliptical orbit.

ELLIPTIC MOTION. Motion along an ellipse. An instance of elliptic motion is motion in the PROBLEM OF TWO BODIES. Since the motion of many bodies of the solar system (planets, their satellites, Earth satellites) occurs in orbits close to elliptic, elliptic motion is frequently used as the first approximation in stndies of the true motion of a celestial body.



Electrostatic rocket engine: (*a*) schematic diagram; (*b*) diagram of cesium ion engine; (*c*) appearance and reaction jet of a 19-beam ion engine.

1—working fluid (cesium); *2*—pump; *3*—electric power supply; *4*—ionization chamber; *5*—electrostatic accelerator; *6*—ions; *7*—electrons; *8*—electron emitter; *9*—radiation shields; *10*—tungsten ionizer; *11*—ionizer heater; *12*—accelerating electrode; *13*—neutralizing electrode (electron emitter); *14*—electrons; *15*—electric potential values.

ELONGATION OF PLANET. The angular distance of a planet from the Sun in the sky.

EMERGENCY ESCAPE SYSTEM. The escape facility for a space crew in case of an emergency situation of the launch vehicle. Escape in the event of failure during launching or along the take-off path can be effected by ejection (see EJECTION SEAT) and descent by parachute, or by emergency separation of the re-entry body of the spaceship from the launch vehicle by a special solid-propellant rocket. In case of emergency at high altitudes, the crew can be rescued by separating the re-entry body (or the entire spaceship) from the launch vehicle, followed by flight along the re-entry trajectory with atmospheric drag. The emergency escape system must have sensing elements to signalize emergency situations, electronic units for originating the necessary command pulses, and the respective actuating devices of emergency systems (e.g., ejection system, special rocket engine, etc.).

EMERGENCY ROCKET ENGINE. An engine used in the emergency escape system for spacemen. In case of an emergency situation at the launching or the lift-off, the emergency rocket engine separates the spaceship or its manned capsule from the launch vehicle and throws it to a safe distance with a great acceleration.

ENERGETIC EFFICIENCY OF ENGINE. An important property of a rocket engine, characterizing propellant consumption for the development of a preset thrust. The index of engine effectiveness is the specific propellant consumption or, more frequently, the SPECIFIC IMPULSE.

Energetic efficiency

ENERGETIC EFFICIENCY OF SYSTEM OF ORIENTATION. An important characteristic of the system of spacecraft orientation, that determines the total power consumption of the system elements per unit of time (usually, the consumption of electric power and—in the case of systems employing ATTITUDE CONTROL MOTORS—the consumption of the working fluid). The energetic efficiency of the system of orientation is to be as high as possible, since this is a continuously operating system on board the spacecraft; quite often the period of operation of this system is equal to the operating time of the entire spacecraft. When designing systems of orientation, special attention is paid to reducing the power consumption of the system elements and, especially, the power consumption of continuously operating electric motors (e.g., the motors of GYROSCOPES, REACTIVE GYRATING MASSES, INFRARED REFERENCE VERTICALS, etc.).

ENGINE 09. A hybrid rocket engine; propellant components: LOX and solidified gasoline (colophony gelled in gasoline). All the fuel was placed directly in the combustion chamber between the chamber's inner wall and the central pipe (net) with large appertures. Oxygen was fed by the pressure of its own vapours. Thrust was up to 50 kg; chamber pressure, 5—6 at; burning time, up to 15 s. It was designed late in 1932 by GIRD, and captive tests were started in May, 1933. On August 17, 1933, the engine *09* successfully lifted the first Soviet rocket *GIRD-09* to a height of about 400 m.

ENGINE 10. A liquid-propellant engine with a pear-shaped oxygen-cooled combustion chamber. Propellant components: LOX and gasoline. However, chamber burnthroughs during the very first tests (in August, 1933) necessitated design changes and a replacement of gasoline by alcohol. In October, 1933, tests began which proved the engine characteristics to be: thrust, approx. 70 kg; specific impulse, 186 s; chamber pressure, 8—10 at; burning time, 16—22 s. The propellant used was LOX and 78% ethyl alcohol. The engine was developed from January, 1933, by GIRD under F. A. Tsander's supervision. On November 25, 1933, the engine *10* launched the *GIRD-X* rocket for the first time.

ENGINE NOISE. An intensive, up to 10 dB, acoustical noise created by an operating rocket engine, mainly by the JET EFFLUX, but also by vibrating walls, etc. It may cause fatigue acoustical failure of the structure (see ACOUSTIC LOAD).

ENGINE PUMP. The pump that is usually installed on the rocket engine proper to feed the propellant or the working fluid into the engine units: the combustion chamber, gas generator, reactor, etc. (see CENTRIFUGAL PUMP, AXICENTRIFUGAL PUMP).

ENVIRONMENTAL FACTORS. Factors of environment that produce various effects on man in space flight. These factors are subdivided into three groups. Group 1 includes extremely low atmospheric pressure, absence of molecular oxygen, various kinds of radiation, sharp temperature fluctuations, etc. The crew is protected against these factors by SEALED CABINS and PRESSURE SUITS that completely isolate them from the environment. Group 2 includes dynamic factors of flight, such as noise, vibration, accelerations, and weightlessness. Group 3 consists of ecological factors

of the sealed cabin of spaceship, i.e., CABIN ATMOSPHERE, BACTERIAL AEROPLANCTON, ISOLATION, CABIN HABITABILITY, restrictions of motion (see HYPOKINESIA), emotional stress, regimen of feeding, work and rest, biological rhythm, etc. Casual factors such as illness of crew members, emergency situations, etc., can constitute a special group. Environmental factors may be of short duration (e.g., accelerations, noise) or long duration (weightlessness). The brevity of some factors does not diminish their danger to man.

EPHEMERIS (in astronomy). A tabulation of the position of natural and artificial celestial bodies, the magnitude of variable stars or other parameters characteristic of the motion or other physical properties of a celestial body calculated for a number of successive moments in future. Ephemeris, determined theoretically, facilitates the search for celestial bodies, and the organization of their observation.

EQUATION OF TIME. The interval by which the true Sun is ahead of or behind the mean Sun. Using the equation of time (η) one can find the local solar time m, if the true solar time m_0 is determined by observations of the Sun, e.g., with the aid of solar clock, and using the formula: $m = m_0 + \eta$. The values for equation of time for every day are tabulated in astronomical almanacs and calendars.

ЭРД. The world's first experimental electrical rocket engine of the electrothermal type developed at the GDL in 1929—33. Metal conductors (wires) or jets of conducting liquids (mercury, electrolytes) introduced through injectors-electrodes were exploded by electric current in the thrust chamber. The wires were fed into the chamber by a roller-gear mechanism driven by an electric motor. Pulses of electric power were supplied into the engine from an installation which comprised a transformer (100 kV, 10 kVA) with 4 kenotrons and oil-filled capacitors of 40 kV, 4 μF. After trying out the process in the open space with a non-stop pulse operation time of several minutes, the thrust chamber was tested on a ballistic pendulum (see Fig. on p. 357).

ERECTION OF ROCKET. Installation of the rocket on the launcher by means of erectors or cranes. This includes lifting the launch vehicle from horizontal into vertical position and bringing the launcher supports into contact with the launch vehicle's supporting elements, thus transferring the weight of the launch vehicle to the launcher. To do this, either the erector mechanisms lower the launch vehicle or the launcher supports are lifted. Erection is difficult due to wind loads that cause irregular oscillations of the launch vehicle and, consequently, of its base. In cases when cranes are used, the individual stages are usually assembled into the launch vehicle on the launcher proper, this operation being termed the vertical assembly. Launch vehicles in assembly may also be erected by cranes. After erection, the rocket is vertically aligned.

ERECTOR. A unit used for the installation of the launch vehicle on the launcher in vertical position and, if necessary, for taking it off the launcher. Arm-type and gantry-type erectors are known. Erectors of the first type consist of a frame, arm with cradles and grips for fixing the launch vehicle, a hydraulic system with hydraulic jacks, and control devices. The launch

vehicle is placed by a crane on the erector arm (and is fixed to it) or is rolled onto the arm together with the transport trolley. The arm is hinged to the frame and can be lifted by the hydraulic jack into vertical position, thus suspending the launch vehicle above the launcher. If further approach of the launch vehicle supporting elements to the launcher supports is performed by means of the erector itself, the erector arm is equipped with moving carriages. Erectors of the second type are usually truck-mounted and comprise a frame, gantry, hydraulic system and hydraulic jacks, hoisting mechanisms, a system of pulleys with removable blocks, and control devices. Transport trolley is indispensable. The trolley with the launch vehicle on it is brought up to the launcher and hinged to the latter. The erector is positioned on the other side, and the hydraulic jacks lift the gantry into vertical position. The removable blocks of the pulley system whose ropes are passed over the upper blocks of the gantry, are fitted to the journals of the trolley, and the hoisting mechanism is set into operation. As a result, the ropes of the pulley system are wound on drums, the transporter is lifted into vertical position and the launch vehicle is suspended above the launcher.

The erectors are either mobile or stationary. Mobile erectors are equipped with a chassis for travelling along motor roads or railways; they are also fitted with support jacks for improving the vehicle stability in operating position. Stationary erectors are installed on the launching site close to the launcher. Mobile arm-type erectors are also used for transporting the launch vehicle from the maintenance area to the launching pad.

ERECTOR ARM. A metal truss structure hinged to the frame of an arm-type ERECTOR. Cradles with grabs for supporting the launch vehicle are mounted on the erector arm. The erector arm is raised into vertical position by means of two or four telescopic hydraulic jacks operating in a parallel or series-parallel fashion. The lifting mechanism is remote controlled from the erector console or from the control centre.

ERECTOR GANTRY. A C-shaped metal structure articulated to the frame of a gantry-type erector. The upper part of the erector gantry carries blocks and ropes of a pulley block system. Before use, the erector gantry is lifted to the vertical position by hydraulic jacks. In this position it serves as a supporting arm for the ropes of the pulley block system and ensures the erection of the trolley carrying the launch vehicle.

EROSION. Damaging or destruction of a solid surface, caused by mechanical action of a fluid stream, in particular in cases of cavitation or when the fluid carries solid particles. The process of erosion mostly affects pump impellers, injectors, nozzles, automatic equipment, and other components of rocket engines.

EROSIVE BURNING. A phenomenon observed in solid-propellant engines charged tightly. When the velocity of combustion products motion along the burning surface exceeds a certain limit (approx. 100 m/s), an increase in the burning rate is observed. Practically, erosive burning is witnessed only in the initial period of engine operation.

ERROR OF ORIENTATION. The angular deviation of spacecraft axes from pre-set directions due to DISTURBING MOMENTS and imperfect performance of the system of ORIENTATION. The permissible error of orientation depends

on the task in question; solar-cell batteries and low-gain antennas may be oriented within 10—15°, while high-gain antennas, cameras for photographing the Moon or Earth surface and instruments for other investigations need an orientation within 1—2°. Accurate manoeuvring and astronomical observations tolerate an error of orientation of a few angular minutes and even seconds.

ESCAPE CONE. A solid angle (cone-shaped, with a vertical axis) at a point in the EXOSPHERE inside of which the probability of collisionless escape of particles from the atmosphere is sufficiently high (e.g., not less than 0.5). The escape cone widens with height; at a given height the angle of the cone is determined by the concentration of the particles, the scale height and gas kinetic collision cross section. The trajectories of escaping particles lie within this cone.

ESCAPE VELOCITY. See HYPERBOLIC VELOCITY, PARABOLIC VELOCITY, SECOND COSMIC VELOCITY, THIRD COSMIC VELOCITY.

ESNAULT-PELTERIE, Robert (1881—1957). French scientist. Elected to the Paris Academy of Sciences in 1936. He graduated from the Sorbonne University, Paris, and devoted himself to the advancement of aviation. In 1908 he received a pilot certificate; earlier, in 1906—1907, he had developed the first monoplane. He also invented the "joy-stick" system of aircraft control and the radial engine for aircraft. In 1912, he began work on the theory of reactive motion, his publications on the subject appearing in 1913 and 1928. His work *L'astronautique* was published in 1930—1935.

ESRO. The name of a series of scientific satellites created by the European Space Research Organization (ESRO). *ESRO-II* was launched on May 17, 1968, and *ESRO-I* was launched on October 3. The American *Scout* launch vehicle was used. The satellites weighed 75 and 84 kg; their orbits had apogees of 1084 and 1532 km, respectively. Their missions were a study of charged particles and X-radiation (*ESRO-II*) and investigation of geomagnetic phenomena in the ionosphere (*ESRO-I*). Another satellite developed by ESRO to measure magnetic fields, cosmic radiation and solar wind was the *HEOS-I* injected into orbit by an American launch vehicle on December 5, 1968; its apogee was $\sim$ 220,000 km.

ESSA. A series of American meteorological satellites. Two satellites of the *Essa* type were launched in 1966. They carried TV equipment for investigating nebulosity.

ETHYL ALCOHOL C_2H_5OH. A colourless, high-boiling liquid fuel; density 0.789 g/cm^3 at 20°C; m.p. —114.6°C; b.p., 78.5°C. Miscible with water and other alcohols; chemically stable; does not attack structural materials. In 1930—1960, ethyl alcohol with a water content of 15—25% by weight (to facilitate cooling of the engine chamber and for economical considerations)

was used in combination with liquid OXYGEN. Later it was substituted by more effective fuels. Proposed by G. Oberth in 1923.

European Launcher Development Organization

EUROPEAN LAUNCHER DEVELOPMENT ORGANIZATION (ELDO). Founded in April, 1962, with member-countries: Australia, Belgium, France, German Federal Republic, Italy, Netherlands and United Kingdom. The programme envisages the development of a multistage launch vehicle for sending Earth satellites into orbits. ELDO is developing the *Europa-1* three-stage launch vehicle for which the United Kingdom is to supply the 1st stage, France, the 2nd stage, and the German Federal Republic, the 3rd. Italy is to provide satellite test vehicles, Belgium will construct an Earth tracking station, the Netherlands together with Italy will produce telemetry equipment for the 3rd stage of the launch vehicle and radio equipment for the ground stations. Australia will place its firing range at Woomera at the disposal of ELDO.

EUROPEAN ORGANIZATIONS FOR SPACE RESEARCH. The organizations of West European countries aimed at joint space efforts (design, production and launching of space vehicles, spacecraft, etc.). One of these bodies is the European Space Research Organization (ESRO) founded in June, 1962, and membering: Belgium, Denmark, France, German Federal Republic, Italy, Netherlands, Spain, Sweden, Switzerland and United Kingdom. The aims of ESRO are to provide for and to promote collaboration among West European countries in space research and technology for peaceful purposes. ESRO headquarters are located in Paris. The organization has 5 basic centres: the European Space Technology Centre (ESTEC) at Noordwijk. Netherlands, which coordinates the space-vehicle development programmes; the European Space Research Laboratory (ESLAB) also at Noordwijk, which handles development of scientific experiments involving spacecraft; the European Space Research Institute (ESRIN) at Frascati, Italy, which is engaged in studies of the physical and chemical phenomena observed in the upper atmosphere and in outer space; the European Space Data Centre (ESDAC) at Darmstadt, GFR, which computer-processes data telemetered from spacecraft; the European Sounding-Rocket Launching Range (ESRANGE) at Kiruna, Sweden. The organization will have its network of spacecraft tracking stations. The scientific programme of ESRO includes: the launching of sounding rockets (approximately 50 a year), the development and launching of light-weight (about 80 kg) satellites using the US solid-propellant launch vehicle *Scout*, of satellites weighing about 400 kg using US *Thor-Delta* launch vehicle, the launching of a 100-kg satellite into a highly elliptical orbit using the same launch vehicle, and a large astronomical satellite (800 kg) using the rocket now under development by ELDO.

EUROSPACE. An industrial association established in September, 1961, with the purpose of encouraging the development of space research and engineering in Europe. Its membership of 150 firms of 12 European countries includes all the aerospace companies, and companies with interest in electronics, chemistry, precision engineering, etc. Eurospace submits to European countries and organizations ideas and views relating to space research. In the opinion of specialists of Eurospace, the basic goal of the European countries is to launch Earth satellites for radio and TV communications.

EVAPORATOR. A heat exchanger in which the heat transfer is accompanied by evaporation of the working fluid (heat carrier or refrigerant). The evaporators are used for cooling air, oxygen, etc., the refrigerant being water, freon, etc. The LSS of spaceships operating in weightlessness may use either (*a*) vortex evaporators where, by twisting the coolant flow in stationary channels or directing it through rotating channels, an artificial gravity field is generated; or (*b*) evaporators with capillary materials where the forces of surface tension in the capillaries of the packing spread the refrigerant over the heat-exchange surface (see GASIFIER)

EXCESS-OF-OXIDIZING-ELEMENTS COEFFICIENT. The ratio of the total weight, in moles, of oxidizing elements (oxygen, fluorine, etc.) contained in the components of the rocket propellant, to their total stoichiometric weight at which only products of complete combustion are obtained. This is one of the principal parameters of a rocket propellant, which substantially affects the temperature and composition of the reaction products. When propellants burn in the combustion chamber, the average value of the coefficient is <1, but in most cases close to 1 (due to the necessity of creating a maximum specific impulse or maximum effectiveness, and cooling the thrust chamber of liquid-propellant engines). Sometimes in various zones (radially and longitudinally) of the combustion chamber and gas generator of liquid-propellant engines, different values of the coefficient are established in order to achieve stability of the process; at the walls, the mixture is over-enriched or over-depleted to attain local reduction of the temperature of the gases and to create reducing or oxidizing screens. For gas generators of liquid-propellant engines, the value of the excess-of-oxidizing elements coefficient is $\ll 1$ (0.1—0.3 for reducing gas generators) or $\gg 1$ (10—25 for oxidizing gas generators which is determined by the maximum permissible temperature for the products of gas generation.

EXCESS-OF-OXIDIZER COEFFICIENT. The relationship between the actual oxidizer-fuel ratio in the rocket propellant and the stoichiometric ratio, i.e., the one at which only products of complete combustion are produced. It is equivalent to the excess-of-oxidizing-elements coefficient if the oxidizer does not contain atoms of the fuel, and the fuel does not contain atoms of the oxidizer.

EXHAUST-GAS DUCT. An element of a silo-type hard or semi-hard launcher intended to convey the efflux of the rocket engine from the FLAME DEFLECTOR to an area where it is harmless for the launch vehicle and ground equipment. Launchers are provided with 1 to 4 exhaust-gas ducts whose walls are lined with heat-resistant grades of concrete or sheet metal. An important parameter of the exhaust-gas duct is its least cross-section area. An insufficient cross-section area may cause reversals of the gas flow while an excessively large section is objectionable due to an increase in the amount of construction work and, consequently, a higher cost of the launcher. The required cross section of the gas-discharge duct is assessed by the coefficient of induction, parameters of the jet efflux, etc.

EXHAUST VELOCITY. The average axial velocity of the gas stream at the nozzle exit of a rocket engine. It is a most important parameter of the rocket engine determining its energetic efficiency (SPECIFIC IMPULSE). When the

exhaust velocity increases, the propellant consumption decreases, the thrust and other conditions being equal. Exhaust velocity of solid-propellant engines is 2—3 km/s, that of liquid-propellant engines, 3—5 km/s. Nuclear rocket engines with a hard-core reactor have an exhaust velocity of 7—9 km/s, with a gas core reactor, 15—25 km/s, electrical rocket engines, from 5 to 100 km/s.

EXOBIOLOGY. The science concerned with life on celestial bodies unrelated to terrestrial life through common origin. It is sometimes referred to as astrobiology which has been developed as yet only on a theoretical basis. In view of the fact that the very concept of "life" is now debated and has no final definition, exobiology is understood in either of two ways.

(1) Presuming that all life must be of the terrestrial type, i.e., carbon-based, with water as the biological solvent, the object of exobiology would be to ascertain the boundaries of Earth-like life (allowable range of temperatures, pressures, etc.) and prediction of the planets (stars) on (or near) which such life is possible. It has been demonstrated experimentally that the boundaries of life are very wide. The upper temperature limit, for example, is determined by the boiling point of water (at a given pressure); a lower limit practically does not exist (considering the possibility of temporary anabiosis). Even higher is the adaptability of life to environments with widely different characteristics. Of the planets of the solar system, Mars is the only one where life may be expected. This hypothesis, however, has not yet been verified. Points in favour of the hypothesis of life on Mars are the changes, coinciding with the planet's seasons, in the brightness, colour and polarization of the so-called seas (dark regions), their ability to resist burial by sand during frequent dust storms. The development of the idea of life on Mars owes much to G. A. Tikhov. He and other authors advanced hypotheses as to possible forms of Martian life, but these hypotheses must be verified by observations. Under development at present are automatic biological laboratories and certain instruments to be borne by SPACE PROBES, intended for direct detection of life on Mars. They make use of such manifestation of life as turbidity of nutrient media due to multiplication of micro-organisms; evolution of labelled CO_2 in metabolism; activation of some reactions by adenosine triphosphate, which is characteristic of protein-based life, etc. Possible discovery of micro-organisms in meteorites has not been confirmed. Organic compounds of the type of carbonaceous chondrites (including cytosine, amines, purine, aliphatic hydrocarbons, etc.) isolated from meteorites, apparently have a non-biogenic origin, since they do not possess optical activity. As to other stars, life of the terrestrial type is most likely to be found on those of the F5 spectral class and later ones which may be expected to possess planetary systems.

(2) If life is possible on some other material basis, the field covered by exobiology widens considerably. Attempts have been made, indeed, to theoretically construct "biochemistries" in which the place of carbon is taken by silicon Si, the boron-nitrogen (B-N) group, etc. Ammonia NH_3, hydrogen sulphide H_2S, hydrofluoride HF, etc. have been suggested as alternative biological solvents instead of water. The possibility of such "biochemistries"

is still debated. If, however, they are possible, the range of heavenly bodies on which life could develop, expands almost infinitely.

EXOSPHERE. The region of the UPPER ATMOSPHERE from where dissipation of particles into interplanetary space is possible. In exosphere the free path of neutral particles in the horizontal direction exceeds the scale height with more than 50% probability. Near the lower boundary of exosphere, which is assumed to pass at the level where $1/e$ of the atoms with thermal velocities above the parabolic velocity dissipate into interplanetary space, the free path materially depends on the direction of motion. In the case of upward movement of a particle within the escape cone it is highly probable that this particle will escape from the dense atmosphere without collisions; the divergence of the escape cone increases with height. Depending on size and direction of the velocity imparted in the last collision, such a particle may move over a hyperbolic or parabolic trajectory (in which case the particle is dissipated or lost irretrievably in interplanetary space), or over a more or less elongated elliptical trajectory around the Earth (in this case the particle sooner or later returns into the Earth's atmosphere). The life of such particles moving in elliptical trajectories and not descending below the boundary of the exosphere is limited by rare (but nevertheless occurring) collisions with other particles of exosphere or by the ionization of these atoms upon collisions with charged high-energy particles existing in the MAGNETOSPHERE, or under the action of the Sun's UV radiation. The life of neutral particles of hydrogen and helium, limited by photoionization, exceeds 10^7 s. The rate of dissipation rapidly increases as temperature of atmosphere grows up. Due to the relatively small mass and, therefore, relatively high thermal velocity, neutral hydrogen atoms are the first to be involved in dissipation. The rate of evaporation of the atmosphere is then determined by the rate of supply of hydrogen atoms to the lower boundary of exosphere by diffusion. At very high temperatures (approximately above 3000°K), noticeable dissipation of helium atoms is possible as well. Therefore, at great distances from the Earth (approximately above 2000—3000 km) neutral exosphere is formed almost entirely of hydrogen atoms; at lower altitudes helium, and lower still, oxygen atoms make up a substantial share. The ACCRETION of neutral atoms in exosphere is apparently negligible.

The distribution of concentrations of neutral hydrogen atoms N_n (cm^{-3}) in exosphere found by measuring scattered radiation in hydrogen's UV line at a distance of R in the Earth radii R_e (R_e 6 380 km), according to measurements made by the automatic interplanetary station *Zond-1* in 1964, is characterized by the following data:

R	1.25	1.50	2	3	4	5	6	10
N_n	650	360	190	84	51	36	26~15	

Strictly speaking, it is impossible to determine the temperature of neutral particles in the region of exosphere as a value proportional to their mean square velocity, inasmuch as this mean velocity is different in different directions. Sometimes exosphere is defined as that region of space in which the collisions between particles may be ignored. This definition is less strict, since it does not permit to specify the lower boundaries of exosphere.

Explosive decompression

EXPLOSIVE DECOMPRESSION. A sharp drop in cabin pressure due to explosive depressurization. In case of explosive decompression, the overpressure produces mechanical attack on the lungs and body cavities. The effect of this attack depends on the degree and duration of the pressure drop, the initial pressure before the drop, the amount of air in the lungs (respiration phase when the drop begins), presence of artificial resistance to respiration. The explosive decompression may cause lung damage and extremely acute hemodynamic disturbances of the pulmonary circle (arterial spasms, venous dilatation, paretic state of the capillary walls, hemorrhage in the pulmonary stroma).

EXTRAGALACTIC ASTRONOMY. The branch of astronomy that studies space and stellar systems known as galaxies, beyond the limits of our GALAXY. The galaxies rotate on their axes with periods of hundreds of millions of years. The faster they rotate, the more flattened they become and the stronger is the concentration of stars on their plane of rotation. The stars are also concentrated towards the centre of the galaxies. The nearest galaxies can be seen with the naked eye as faint nebulous spots, such as the Magellanic Clouds in the Southern hemisphere and the Great Andromeda Nebula in the Northern hemisphere. Photography reveals that the galaxies consist mainly of stars and have complicated structures. By means of powerful telescopes, milliards of galaxies can be registered. The main types of galaxies are spirals (flat arms twisted around a nucleus), and elliptical (stars filling space in the form of an ellipsoid and concentrating towards the centre). There are a few irregular galaxies such as the Magellanic Clouds. Also known are several thousand galactic clusters (or clouds), the nearest being the Virgo cluster which is believed to be the nucleus of a flattened system consisting of many thousands of galaxies, including ours. Elliptical galaxies consist only of stars while the spiralled and the irregular ones include also diffuse matter (cosmic dust, neutral and ionized gas) which comprises a small percentage of the total mass. All spirals contain heated ionized hydrogen which radiates energy in the form of visible light and thermal radio emission. Some galaxies possessing magnetic fields and an enormous quantity of protons and electrons (moving with velocities comparable to the velocity of light) radiate strongly in the radiowave range; these are called *radiogalaxies*. In the 1960s other powerful sources of radio waves have been discovered. Known as the quasars, they are dozens of times more powerful than the radiogalaxies though optically they cannot be distinguished from ordinary stars; they are several milliard light years from the Earth. In space flight, radiogalaxies can serve as radio beacons.

EXTRA-TERRESTRIAL CIVILIZATIONS. Societies of intelligent beings on other planets. Extra-terrestrial civilizations probably do not exist within the solar system. Whether there was an extra-terrestrial civilization on Mars in the past, remains an open question. The probability of existence of extra-terrestrial civilizations on planetary systems of other stars cannot be estimated with any degree of reliability. In the 17—19th centuries it was commonly believed that practically every planet and even the Sun were inhabited. At present the probability of an extra-terrestrial civilization at a separate star is estimated to be no more than 10^{-6} or even much less. The absence of intel-

ligent signals in the rapidly increasing volume of information accumulated by modern astronomy, convinces an ever larger number of researchers of the extreme rarity of an extra-terrestrial civilization (not more than a few extra-terrestrial civilizations per Galaxy, i.e., per 10^{11} stars). Scientific analysis of the problem of an extra-terrestrial civilization is concentrated on determining the probability of formation of a planetary system (where planets have conditions suitable for the development of life) by stars of different types, the possibility of life appearing on a planet and evolving towards intelligence. What makes these studies difficult is that only one sample of a planetary system and life is known. Most disputable is the question of the life-time of a highly-developed civilization (the so-called technological era). In particular, it is this that determines the energy resources of an extra-terrestrial civilization and, in the last analysis, the possibility of detecting it.

EYRAUD, Achiles. A French writer, author of a novel *A Voyage to Venus* (1865) wherein the interplanetary travel in a rocket craft propelled by engines using water as working fluid is described. His name was given to a crater on the far side of the Moon.

F

FEOKTISTOV, Konstantin Petrovich (born 1926, Voronezh). Pilot-Cosmonaut of the USSR. Dr. Sc. (Engineering). Hero of the Soviet Union. World War II veteran; was wounded in 1942. Finished a secondary school in 1943 and graduated from the Moscow Higher Technical School in 1949. Took his M. Sc. (Engineering) degree in 1955. As a researcher, made a space flight together with V. M. KOMAROV and B. B. YEGOROV on October 12, 1964, in the *Voskhod* multiman spaceship.

FILLER CONNECTOR. A quick-release connector that tightly joins propellant-loading pipelines to the filling neck of launch vehicle tanks. The filler connector is a combination of a quick-release coupling and a non-return valve.

FILM COOLING. A method of cooling the walls of the thrust chambers, gas generators and other units of rocket engines. It is used to protect walls from high heat-transfer rates when external cooling is insufficient, and to protect walls against chemical action of hot gases (see COOLING OF ROCKET ENGINE). Film cooling is usually realized by feeding the fuel through slits or orifices in the wall, thus creating a fuel film. As the fuel in the film moves, it gradually evaporates absorbing the excess heat for evaporation. The fuel vapours enter the boundary layer, and increase its thickness which decreases heat output. A gas screen with a temperature lower than that of the gases in the approaching stream appears after evaporation and destruction of the film, and it also protects the walls.

FILTRATION OF GASES. Purification of process gases to clean them of moisture and mechanical impurities by means of filters and moisture-and-oil separators. The mechanical impurities must be removed from the gas to avoid erosion of valve seats of pneumatic equipment and pressure reducers whose throttling devices pass the gas, in most cases, at a supersonic speed. The elimination of moisture and oil is necessary to prevent their crystallization in the jet and throttle apertures of the reducers and the valve seats, where the gas expansion decreases the temperature. The precipitation of ice crystals and hoarfrost can contaminate the gas supply system and impair the tightness of the pneumatic equipment.

FILTRATION OF PROPELLANTS. Purification of rocket propellants in the propellant-loading system of a space centre in order to clean them of solid particles and mechanical impurities by means of filters. Rocket propellants should not contain mechanical particles larger than 70 μ, and in many cases, larger than 20 μ. Propellants are usually cleaned at the launch complexes by mechanical filters with filtering elements containing one or several metal grids of different mesh sizes, or by porous substances.

FINS. Airfoils arranged on the rocket tail for aerodynamic stability. The fins cause a rearward displacement of the centre of pressure of aerodynamic forces affecting the rocket during its flight through the atmosphere and, as a result, ensure aerodynamic stability of the rocket. The fins are usually built up of a framework of spars and ribs covered by a thin-wall outer skin; the framework of the fins is attached to the frames of the rear-end unit of the rocket.

FIRE-FIGHTING SYSTEM OF LAUNCHING SITE. A system protecting the launch vehicle against accidental ignition of spilled propellants in gas-

discharge ducts of the launch structure. The protection is accomplished by setting up a circular water curtain, as well as by extinguishing on-pad fires by directing streams of water from carriage-mounted spouts to the areas on fire. The fire-fighting system comprises pumping units, water intake and delivery manifolds, a reservoir with technical water, hydraulic accessories, a circular header of the water curtain, carriage-mounted spouts, and the equipment for remote control. The circular header is situated on the launcher around the launch vehicle and supplied with a number of nozzle jets to build up the water curtain. The carriage-mounted spouts can be lifted and lowered, swivelled to the left and to the right; manoeuvres of the carriage-mounted spouts are brought about by means of remote-controlled hydraulic actuators. Control of the carriage-mounted spouts and opening and closing of the electrically or electromagnetically operated hydraulic valves are also performed remotely from the control desk.

Flame deflector

FIRING KEY. The key for closing the electric circuits of the launch control console. It is kept in a separate place and inserted into the keyhole of the control console only on appropriate orders, to rule out an unauthorized energizing of the control console systems.

FIRING SYSTEM. See LAUNCHER.

FIRING TESTS. Testing of rocket engines at operational rates of propellant burning. Hold-down firing tests are carried out with separate rocket engines or those installed in a rocket stage. Besides, there are flight firing tests when rocket engines act as a part of the rocket (see TESTING OF ROCKET ENGINE).

FIRST COSMIC VELOCITY. The minimum initial velocity that a body must acquire to become a satellite. It is equal to the circular velocity. The first cosmic velocity varies with altitude. At the Earth's surface the first cosmic velocity is about 7.91 km/s (air resistance disregarded).

FLAME CHUTE. A device comprising a single-slope FLAME DEFLECTOR and an EXHAUST-GAS DUCT. This launcher element of U-type section (in the form of a chute) directs the rocket efflux to the zone where it is harmless for the launch vehicle and the equipment.

FLAME DEFLECTOR. A launcher element intended for directing the high-temperature supersonic efflux of the launch vehicle engine to where it will not bring harm to the vehicle and ground equipment. The deflector comprises shaped deflecting surfaces, walls and gas baffles. The deflecting surfaces consist, as a rule, of a flat and a curved part. The durability of the flame-deflecting surfaces is ensured by selecting adequate materials, wall thickness and special coatings; sometimes the deflecting walls have embedded tubes for circulating a cooling liquid. The design of the flame deflector depends on the parameters of the jet efflux, the number, size and location of the engine jet nozzles, and the type, design and installation depth of the launcher. The height of the launcher is often determined by the design of the flame deflector. Depending on the number of deflecting surfaces, the flame deflectors can be of the single-, double-, tripple- quadruple- and sextuple-slope type. Sometimes one flame deflector is provided for two launchers; in this case it is allotted rail mobility. The engine jet impinges directly on the flame deflector; the deflected stream moves sideways and sometimes, as in silo-type hard

or semi-hard launchers, passes through exhaust-gas ducts, chutes, gas pipes, etc. In some cases the engine jet is directed from the flame deflector into water.

FLIGHT CONTROL. The character of motion of a space vehicle (an assembly consisting of the launch vehicle and the payload, i.e., the body put into orbit) depends upon the phase of the flight and the task to be fulfilled. This motion may fall into one of the following two types: (1) motion independent of considerable external forces and/or moments (including the forces of universal gravitation), with the rocket engines cut off; (2) motion with rocket engines operating, or effected by considerably large external forces and/or moments, or under the combined influence of the two factors. The 1st-type motion takes up most of the flight time whereas the 2nd-type motion is experienced during take-off and injection of the spacecraft into orbit, as well as during re-entry and short-time operation of the rocket engine for changing the flight path. Motion of the 1st type is distinguished from practically all other types of motion by that the motion of the mass centre is completely independent of the angular rotation of the spacecraft about the centre of mass. In this case, the only appreciable forces acting on the spacecraft are the forces of universal gravitation that do not depend on the angular position of the spacecraft in space. Therefore, the flight path remains the same regardless of whether the spacecraft rotates erratically about the centre of mass, or has a fixed angular attitude with respect to the Sun and stars, or changes its angular attitude regularly. This independence of the flight path on the rotation of the spacecraft about the centre of mass does not imply that there is no need of controlling the angular attitude of the spacecraft. The control system that brings the spacecraft into the required attitude is called the orientation system and the process is called ORIENTATION. E.g., in order to change the flight path it is necessary to turn the spacecraft so that the thrust of the rocket engine acts in the required direction, this being accomplished before the engine is actually started. In cases when a great amount of information (e.g., a TV picture) is to be transmitted to the Earth from a distant spacecraft, this can be done best of all by the use of parabolic antennas carried by the spacecraft. These antennas are of a directional type and have to be oriented accurately towards the Earth. This necessitates the orientation of the entire spacecraft with respect to the Earth in cases when the antennas are fixed rigidly to the spacecraft. SOLAR BATTERIES mounted on a spacecraft have to be oriented towards the Sun for normal operation. Navigational measurements with reference to celestial points can also be made only after positioning the spacecraft so that the required stars can be seen by the crew. Many scientific experiments cannot be conducted satisfactorily unless the spacecraft is properly oriented.

Motion of the 2nd type also requires control of the angular attitude since the direction of the forces that determine the trajectory of the centre of mass, i.e., the forces of the engine thrust and aerodynamic forces (when travelling through an atmosphere), depends upon the attitude of the spacecraft. Rotation of the vehicle about its centre of mass changes the motion of this centre or, in other words, affects the flight path. In such cases, the process of attitude control of spacecraft is called stabilization and the control system used

for this is called the stabilization system. Orientation differs from stabilization in that rotation about the centre of mass during the process of orientation does not affect the motion of the centre in any way. Thus, in the 1st case an independent task is fulfilled, whereas in the 2nd case auxiliary control of the angular attitude necessary for changing the motion of the centre of mass is provided. Systems of orientation and stabilization are quite frequently closely associated and sometimes even employ the same sensors. Thus, when two spacecraft that are far apart have to be brought alongside each other, the rocket engines are repeatedly started for short periods of time followed by fairly long shutdown intervals and the process of approach calls for alternating orientation and stabilization of the space vehicle.

Flight control

Flight control involves direct control of the spacecraft motion along the trajectory, as well as stabilization of the spacecraft. The most simple case is when the rocket engine is operated for a short period of time and cut off at attainment of the required velocity. To this end, the spacecraft is to be equipped with a device capable of recording the moment at which the required velocity increment has been obtained and delivering the command to cut off the rocket engine. In more complicated cases when it becomes necessary to attain the required velocity at a specific point in space, the thrust of the rocket engine is to be controlled continuously so that the flight trajectory and the moments of time at which the launch vehicle reaches reference points of the trajectory are in conformity with precomputed values. In this case, the rocket engine is also to be cut off at attainment of the required velocity.

Another important object that is pursued by controlling the motion of the centre of mass is the determination of the actual trajectory and its correction whenever this becomes necessary. The actual trajectory of the spacecraft can be determined by taking measurements with the aid of Earth-based radio equipment. The ground service of TRAJECTORY MEASUREMENTS using high-speed electronic computers enables to keep track of the flight. Such a combination of measuring and computing facilities is an example of a cooperative system of navigation if navigation is limited to the determination of the spacecraft coordinates, forecasting of its motion and computation of the forces necessary for correction of the motion. Besides cooperative systems of navigation, there are also self-contained systems that do not need any communication with ground stations and operate by the sole use of spaceborne equipment. Thus, the three following tasks fall into the scope of control and navigation: control of the motion of the centre of mass (including stabilization), orientation, and navigational measurements and computations.

The take-off of the launch vehicle and injecting of the space body into orbit is one of the most formidable tasks fulfilled by controlling the motion of the centre of mass. The best way to attain cosmic speeds is by boosting the spacecraft horizontally so as to avoid the necessity of overcoming the opposing forces of gravity. The curvature of the Earth and the fact that horizontal flight implies a motion at equal distances from the Earth's centre are to be taken into account since the boost trajectory may be of a great length. Therefore, the launch vehicle is to rotate (pitch) in the orbital plane during

the boost period in order to follow the circle. Such a motion is possible only at high altitudes where no atmosphere is encountered. On the other hand, the launch vehicle can be launched only in vertical position as its great size necessitates an unwarranted strengthening (and a consequent weight penalty) of the rocket shell and the use of a more powerful engine if it is launched from an inclined position. Another reason for which inclined launching is impractical lies in the fact that the spacecraft is to ascend through the dense atmosphere along the shortest path and at a relatively low speed so as to minimize power losses for air drag. The trajectory of the spacecraft, initially vertical, is to become gradually inclined during the ascent so as to follow an approximately concentric circle around the Earth at sufficiently high altitudes. This makes it necessary to start the pitching motion almost immediately after launching. The longitudinal axis of the rocket must pitch in accordance with the required trajectory of ascent and subsequent boost. The boost trajectory is precomputed so as to be the most favourable for each specific launch, i.e., this trajectory and the manner in which the pitch angle is to be varied are known beforehand. Therefore, one of the main objects of the system of stabilization is to perform the pitching in such a way that the roll and yaw angles of other axes of the spacecraft are nearly zero throughout the process of pitch control. It is practically impossible to keep the pitch, roll and yaw angles ideally at preset values since they are subject to constant fluctuation. Besides that, the centre of the launch vehicle mass does not lie perfectly on the force line of the rocket engine thrust and this also causes a certain rotation of the rocket axis. However slight these rotations and fluctuations may be, the final result is that the engine thrust produces a minor motion in the plane normal to the required direction of flight and causes a side drift of the launch vehicle. This is quite inadmissible as it worsens the accuracy of the spacecraft injection into orbit. Therefore, the system of stabilization is provided with special sensors that are capable of responding to the side drift and sending command signals to the control system.

Free GYROSCOPES or GYROSCOPE-STABILIZED PLATFORMS are commonly used as sensing elements for determining the angles of rotation of the launch vehicle axes. These instruments are equipped with programming devices for accomplishing the pitching motion. The drift of the launch vehicle is recorded by lateral velocity indicators whose operation is based on the measurement of the lateral acceleration by some suitable method. The signals indicating the angular displacement of the launch vehicle axes can be utilized for determining the angular velocity of the rocket; in certain cases this is achieved by the employment of a gyro-type angular-rate sensor. The sensing element signals are supplied to amplifying and converting devices that produce signals delivered to the system actuators (e.g., to gimballed rocket engines).

The stabilization of the launch vehicle is frequently complicated by bending and longitudinal vibrations of the airframe and oscillation of propellant in the rocket tanks. The launch vehicle has quite often not only to boost the spacecraft to the required velocity, but also to attain this velocity at a specific point in space. Such a necessity arises in cases when a specific inclination of the flight trajectory with respect to the Earth is required after the

spacecraft has been boosted by the launch vehicle into orbit. The attainment of a preset velocity at a specific point calls for control of the launch vehicle velocity during the powered flight phase. The variation in flight velocity depends on whether the rocket engine thrust is increased or decreased, i.e., on control of the engines, and can be accomplished by comparing the actual change in velocity with a preset programme of variation of the flight velocity. This task is performed by an APPARENT VELOCITY REGULATOR, wherein the velocity is computed in the course of the flight according to accelerations measured by ACCELEROMETERS. The latter, however, not only measure the accelerations of the launch vehicle, but also record inevitably the level of terrestrial gravity. Therefore, the results of the above computations reveal the apparent velocity instead of the actual velocity. This does not necessarily introduce any control error, since the contribution of the gravitational field is known beforehand for every point of the flight path and the computed values are compared with a pre-established programme of variation of the apparent velocity. Thus, the velocity regulator is to adjust the operation of the rocket engines at any deviation of the actual value of the apparent velocity from that provided for by the programme. The operation of the system that cuts off the rocket engine at attainment of the required velocity is closely related with the operation of the apparent velocity regulator. Control of a rocket engine and stabilization of a launch vehicle are performed much easier in case of simple MANOEUVRES, such as trajectory corrections in long-distance flights, orbital corrections in circumterrestrial flights, transfer of an Earth satellite to a descent orbit, etc. In these cases the manoeuvre is achieved by a short-time operation of the rocket engine, and programmed pitching and control of the apparent velocity are not required.

Flight control

The process of landing a spacecraft on a planet having no atmosphere (e.g., the Moon) is nearly as complicate as that of launching. In such cases, especially when the landing is performed from a circumlunar orbit, highly accurate control of the descent trajectory (that is to be horizontal at the initial stage of descent and vertical at close approach to the surface of the Moon) and the flight velocity (that is to be zero on reaching the surface of the Moon) is required. It is also advisable to employ a radar altimeter whose signals indicate the actual distance from the surface (this distance may differ from the average owing to the relief of the planet). Stabilization as well as apparrent-speed control of the spacecraft is necessary for controlling the landing engine (retrorocket).

Unlike the stabilization and thrust control operations that are practically always performed by the same means, orientation is accomplished by different methods depending on the set task (orientation with reference to the Sun, Earth, stars, etc.), degree of accuracy (from angular minutes and even seconds necessary for ASTROORIENTATION or scientific experiments to 10°—20° when orienting solar batteries), and the required period of orientation (from a few minutes or hours to several months and even years). Therefore, a great variety of methods and means are used for orientation. Existing orientation systems are divided into 2 types: complete (triaxial) and partial (single-axis) systems of orientation. The 1st type covers systems that orient all the 3 mutually perpendicular axes of the spacecraft and maintain them in preset

position. Systems of the 2nd type orient a single preselected axis, whereas the other 2 axes may occupy any random position; such systems are employed for orienting solar batteries. Another classifying feature may be the properties of the axes of orientation with respect to which the spacecraft axes are to be oriented. It is assumed that these axes are also mutually perpendicular and, alike the spacecraft axes, originate at the centre of mass of the latter, but that the law of their angular motion does not depend in any way on the motion of the spececraft. Three different cases may occur. The 1st is characterized by a translational motion of the axes during which they remain parallel to themselves; when the spacecraft is oriented with reference to these axes it retains a constant angular position with respect to stars. Such axes are convenient for orienting with respect to the Sun and stars. The 2nd case applies to orbital axes of orientation that rotate during orbital flights around the Earth or some other celestial body so that one of the axes is directed towards the centre of the celestial body, another lies in the orbital plane, and the third is perpendicular to this plane. Such axes are used by systems of satellite orientation when the satellite is to move in a "natural" manner so that one of its sides is always directed forwards and another is always downwards; in this case the required orientation is brought about by referring all three axes of the satellite to the three orbital axes. Axes of orientation of the 3rd type are called tracking axes and are such as, e.g., the axis along which spacecraft approach each other. These axes are not subject to any orderly (translational or rotary) motion, but move at random according to the mutual position occupied by the spacecraft in the course of approach.

Depending on the method used for obtaining the required moment of orientation, all existing systems of orientation can be classified as active, passive and combined. The controlling moment of active systems of orientation is obtained by the consumption of a certain amount of power supplied from space-borne sources or by the utilization of a reactive force (e.g., by starting the attitude control motors), which also consumes some of the space-borne working fluid. The controlling moments of passive orientation systems are produced by the interaction of the spacecraft with the surrounding medium that may be a magnetic field, gravitational field (e.g., GRAVITATIONAL SYSTEM OF ORIENTATION), etc. This does not necessitate the consumption of any power or working fluid derived from space-borne sources. Combined orientation systems make use of externally obtained moments in the same manner as passive systems, but also employ elements that produce controlling moments by consuming power of working fluid. An advantage of active orientation systems is their flexibility that makes it possible to perform practically any required manoeuvre and ensures accurate orientation under any external disturbances. For this reason, active systems of orientation are the most frequently used. The main advantage of passive orientation systems is that they are very economical. Passive and combined systems of orientation are not used as often as active systems. Depending on the degree of cooperation of the spaceman, orientation systems may be automatic or manual. Manual orientation calls for the spaceman to turn the spacecraft in the required direction by shifting a control handle. Direct control

of the spacecraft by the spaceman makes it easier to accomplish many difficult tasks since man is often capable of making a better and quicker appraisal of the situation and a better decision than is within the means of complicated automatic equipment.

Active systems of orientation operate as follows. Information relating to the position of the spacecraft with respect to the adopted axes of orientation and to the character of its angular motion is supplied to the system of orientation by its sensing elements. Optico-electronic instruments that allow to use celestial bodies (the Sun, Earth, Moon, stars) as points of reference constitute a large group of sensors. Optical sensors convert visible or IR light into electrical signals that vary (gradually or abruptly) when the axis of the sensor deviates from the direction to the reference point. In cases when the Earth serves as a reference point, it is often convenient to record the IR (thermal) radiation since the light and dark (night) sides of the Earth emit an approximately equal amount of this radiation. Sensors responsive to the visible light of the Sun, stars and planets are more frequently used. In some cases, an ionic sensing element may serve as an angular-position pickoff. Magnetic sensing elements that allow to determine the position of the spacecraft with respect to the terrestrial magnetic field may also be used. All the above sensors generate signals indicating the angular attitude of the spacecraft by responding to the effect produced by external points of reference.

Gyro sensors (free gyro, gyro-stabilized platforms, orbit gyro, etc.) whose operation is based on the physical properties of a quickly spinning disc constitute a separate group of sensors. However, these gyrosensors cannot operate unless information is supplied from sensors of the preceding type. In all other respects, gyrosensors are preferable as they are practically insensitive to any interference and are trouble-free in service (e.g., optical sensors are liable to become "blinded" by the rocket engine blast). The spacecraft is quite often equipped with a group of sensing elements employing different operating principles. The operation of angular-rate sensors used in space flights is based on the physical properties of a single-axis gyroscope. Each sensor records the angular-rate component parallel to its own axis of sensitivity. Therefore, 3 sensors are used when it is necessary to determine the components of the angular velocity of spacecraft rotation about the 3 axes.

The signals supplied by the sensors are to be compared and, after conversion, delivered to the actuators. This is performed by a logical unit that is sometimes called a logical conversion unit or simply a converter. The logical unit (that may incorporate several devices) serves for fulfilling two basic tasks: amplification, comparison and conversion of the sensor signals into control signals for starting and stopping the actuators; and performance of logical operations required for normal functioning of the systems of orientation. The method by means of which the sensor signals are compared can be illustrated by the following example: when a roll deviation of the spacecraft is signalled, this does not necessarily mean that the motor that controls the roll motion is to be started immediately to correct the spacecraft attitude. It is, first of all, necessary to compare the roll deviation signal with the signal received from the respective angular-rate sensor. If this comparison reveals that the angular rate tends to increase the roll, it is then really neces-

sary to start the attitude control motor; if the angular rate tends to reduce the roll angle, the spacecraft will return to correct position on its own account. Moreover, operation of the motor in such a situation will cause the spacecraft to approach the correct position at a high-angular rate and "overshoot" it due to inertia so that it will be necessary to slow down the angular velocity by starting the attitude control motors acting in the opposite direction. This worsens the accuracy of orientation and leads to unjustified losses of power or the working fluid.

The manner in which logical operations are performed can be illustrated by the following example: let it be assumed that a spacecraft flying from the Earth to the Moon has to be fully oriented with reference to the Sun and the Moon. To this end the spacecraft is to be equipped with solar and lunar optical sensors set at a required angle to each other. Since these sensors remain in a fixed position during the process of orientation, the search of the reference points is to be performed by rotating the entire spacecraft. It is evident that these points are to be sought one after the other, this being accomplished, for example, in the following manner: the Sun is located by initiating a rotary motion of the spacecraft while the solar sensor scans the celestial sphere and locates the Sun. After this has been accomplished, the rotary movement is braked, the Sun is kept within the field of view of the sensor and the spective axis of the spacecraft is directed towards the Sun by rotating the spacecraft (thus orienting the latter more accurately); after that, the spacerecraft is rotated about the axis directed towards the Sun (without losing sight of the latter), and the optical axis of the lunar sensor inclined at the required angle to the axis of rotation of the spacecraft circumscribes a conical surface and at a certain moment of this motion finds the direction towards the Moon. Then the rotary motion is braked and the spacecraft is oriented more accurately. Consequently, final orientation is attained in the following stages: rotation—location of the reference point—braking—more accurate orientation—second rotation—location of the 2nd reference point—braking—more accurate orientation towards the 2nd reference point. It is evident that none of these operations can be initiated until the preceding operation has been fully accomplished. Therefore, in addition to the supply of control signals for actuating control elements, the logical unit is to produce signals indicating that the given step in the process of orientation has ended and to initiate the programme of the next step only after such a signal has been received. As a general rule, the system of orientation is to be capable of performing several different types of orientation.

After the sensor signals have been converted by the logical unit, they are delivered to the actuators of the orientation system. The actuators can be grouped into the following two classes: those that produce the control torques by interaction with the environment, and the reaction-type elements. The former class of actuators covers electromagnetic elements (permanent and variable magnets of current-carrying circuits that interact with the magnetic field of the Earth or some other planet possessing a magnetic field). Thus, a spacecraft can be made to rotate about one of its axes by setting up current in one of three current-carrying rings arranged in mutually perpendicular planes. The main disadvantage of such actuators is that a sufficiently strong

external magnetic field is required for their operation (up to the present, no planet other than the Earth has been found to have such a field), and their efficiency depends upon the physical properties of this field. Other actuators of this class are conceivable, e.g., elements utilizing the pressure of solar radiation or aerodynamic moments, but such elements have not been practically employed for orientation. The 2nd class of actuators covers more widely used reaction-type elements, the operation of which does not depend on the properties of the environment, this being their main advantage. Attitude control motors, gyroscopic stabilizers, and reactive flywheels belong to this class of actuators. If the speed of rotation of a flywheel installed on the spacecraft is varied, e.g., increased in the clockwise direction, a counterclockwise rotation of the spacecraft is set up. Therefore, in order to control the rotation of a spacecraft about its three axes, it is sufficient to position three flywheels in mutually perpendicular planes and to vary the speed and direction of their rotation. Attitude control rocket engines are arranged so that their thrust lines which produce controlling moments are at a sufficiently large distance from the centre of mass. The working fluid carried by the spacecraft is ejected out of the engines at a high speed. In the most simple case, the gas for ejection can be stored in the compressed form in space-borne bottles and expelled through the pneumatic rocket engine by opening suitable valves for the required period of time. More efficient systems store liquid propellant that burns in the combustion chamber of the engine and ejects high-temperature gases through the engine nozzle. The main disadvantage of attitude control rocket engines is that in operation they consume propellant that cannot be replenished in flight. Flywheels can be rotated by power derived from and restored by solar batteries. Flywheels, however, are incapable of opposing disturbances for a long time. In cases when an external disturbing moment (e.g., an aerodynamic moment) is applied permanently to one of the spacecraft axes, the speed of the respective flywheels that opposes this disturbance begins to increase gradually and in due time (hours or days) attains maximum value. As a result, the disturbing moment begins to change the attitude of the spacecraft, since further increase of the flywheel speed is impossible. For this reason, reactive flywheels operate in joint with other types of actuators, such as attitude control motors or electromagnetic actuators.

Energetic efficiency of the orientation system is of great importance since it is to consume a minimum amount of electric power and, even more important, of propellant. Weak disturbances are to be opposed by correspondingly slight moments. As a rule, the rocket engine thrust is uncontrollable and, consequently, these engines develop always the same controlling moment irrespective of the character of the disturbance. Owing to this property of the engines, they are operated continuously at considerable disturbances and periodically, for fractions of a second, at slight disturbances. In the latter case, the short-time periods of operation are followed by intervals of a few seconds, which is equivalent of a ten-fold (and greater) reduction of thrust and, consequently, propellant consumption. The logical unit is to supply continuous or pulse signals for operating the attitude control motors in accordance with the signals received from the orientation.

Control of motion of the centre of mass and orientation are combined to a certain extent when performing a manoeuvre for an orbital rendezvous of spacecraft. Two different phases of distant approach and docking are to be distinguished. Information relating to the mutual position of the two spacecraft may be received from the Earth if the distance between them is very great. In this case the active spacecraft (if it is manned) has to perform a certain manoeuvre in order to come up to a distance at which the other spacecraft can be observed visually or with the aid of space-borne instruments, e.g., radar equipment. This is the 1st stage of approach that does not differ in any respect from orbital correction. By corresponding computations (carried out on board the spacecraft or by ground-based computers), the value and direction of the pulse required for changing the orbit are determined, as well as the time of operation of the rocket engine. After these data have been obtained, the spacecraft is oriented as required and the rocket engine is started at the set moment of time, this being accompanied by stabilization of the spacecraft; it may become necessary to repeat this operation several times in succession. The 2nd stage begins when the active spaceship comes up to the other one so closely that the distance between them and the speed of approach can be measured by means of instruments on board the spacecraft. The rocket engines of the active spacecraft are operated according to information relating to the mutual positions and velocities of the two spaceships, the signals being continuously received from the radar and other sensors, so as to accelerate or brake the spacecraft, eliminate lateral drift, etc. This process, as well as the preceding one, consists of a series of orientations and stabilizations performed by operating the rocket engines.

The short-distance phase of approach (docking) calls for the use of slightly different control methods. Means are to be provided for bringing the active spacecraft close up to the passive one, "hovering" near it and, if necessary, flying around it without rotation. This is attained by the employment of six small rocket engines whose lines of thrust pass through the spacecraft centre of mass. Each of these engines when started initiates a slow motion (without rotation) along one of the following three coordinates: un-down, left-right, forward-backward. Such translational motions during the docking phase enable, whenever necessary, to join both spacecraft together, to deliver propellant and food to manned orbital stations, or to fulfil other similar tasks.

Spacecraft navigation is a different problem. In a broad sense, navigation means the determination of one's position (coordinates), forecasting the motion, and supplying of signals to the system of control if forecasts indicate that further motion will cause an inadmissible deviation from the required flight path. In principle, all these operations can be performed automatically by including the navigational instruments, space-borne computer and other devices into the system of automatic control of motion of the spacecraft centre of mass. In a more narrow sense, navigation is limited to determining the coordinates, forecasting the motion and computing the manoeuvres that are to be performed for correcting trajectory errors. This can be done cooperatively by the use of ground-based radio equipment for determining the actual trajectory and subsequent computation of the trajectory at computing centres, but can also be performed by space-borne equipment. The latter

method is of great importance in the event of manned flights to the Moon and other planets when the spaceman is to be able to determine the flight path and make independently all the computations required for trajectory corrections. The errors occurring during the initial phase of the flight are very small due to the high accuracy with which the spacecraft is launched into orbit; however, in the course of long-distance flights (e.g., to the Moon), these errors are liable to grow and cause an ever-increasing disagreement between the computed and actual trajectory, that may eventually become quite inadmissible at approach to the goal. One of the factors causing an increase in the trajectory error is the disturbances caused by planets. Gravitational forces cause a considerable distortion and sharp increase in error of flight paths passing in the vicinity of a planet even if the trajectory corrections have been fulfilled with a high degree of accuracy. Therefore, the trajectory is to be corrected at least twice when flying past a planet: the boost error is to be corrected during the flight towards the goal, and the residual errors increased by the planetary disturbance are to be corrected at return. In order to solve these navigational problems, the spaceman is to have a sextant of sufficient accuracy for measuring the angles between specific stars and the rim of the planet (the Earth or planet of destination). The angles change constantly with the motion along the trajectory. On having obtained a sufficient number of angular measurements and noted the exact time at which they were made, the spaceman introduces these data into the spaceborne computer. The latter computes the entire trajectory and, in particular, the phase in vicinity of the goal, thus making it possible to decide whether a trajectory correction is really necessary. Besides that, the spaceman is to compute the magnitude and direction of the correction pulse and establish the exact moment of correction. This computation is to allow to select the optimum moment of correction. After that, the three axes of the spacecraft are to be oriented with a high degree of accuracy towards the adopted reference points (e.g., stars) and then the rocket engine is started at the right moment of time to apply the required pulse to the spacecraft. After correction, new navigational measurements are made in order to make sure that the correction has been performed successfully or to repeat it after a certain period of time.

Atmospheric descent (re-entry) is a quite different matter. An atmosphere makes the descent easier, not necessarily using retro-rockets, and consequently, allows a sharp reduction in the amount of propellant required for the descent. Atmospheric braking allows to apply a very slight initial pulse to the spacecraft by the rocket engine. It is sufficient to reduce the velocity of the spacecraft from 8 to 7.8 km/s, i.e., by only 200 m/s, in order to incline the trajectory downwards so that the satellite enters the upper dense layers of the atmosphere (at an altitude of 80—100 km) and lands without making a full orbit around the Earth. Such a re-entry is called ballistic, if the re-entry body is not subject to the effect of noticeable lateral forces during the descent. In certain cases, the re-entry body is given a special shape and the centre of the body mass is positioned so that a large ANGLE OF ATTACK is established during the re-entry, thus giving rise to a considerable side force. This force enables to control the descent and land the re-entry body on

a much smaller area of the Earth's surface than is otherwise possible; this is of special importance when the re-entry body is landed in the ocean, as has been chosen for American spacecraft. The descent is controlled by providing the re-entry body with almost the same equipment as is used for stabilization, i.e., with a set of gyroscopic devices, accelerometers and converters. The control signals are to be supplied to the attitude control motors used for rotating the spacecraft, roll control being employed. In the absence of any roll, the side force acts in an upward direction and retards the descent; if the roll equals 180° (the spaceman is head down), the side force is directed downwards and accelerates the descent; in cases when the roll is equal to 90°, the side force does not affect the rate of descent (through it causes a side drift). It is evident that the descent rate can be controlled by varying the roll angle. The descent rate can be compared with the computed value in the following way. The deceleration and, consequently, the resulting overload are known for every point of the computed trajectory; this allows to establish the program of re-entry according to the change in deceleration with time. If the re-entry body moves along a different trajectory during the actual flight, the time dependence of deceleration is also different. Let it be assumed that the actual deceleration exceeds the programmed value at a certain moment of time; this indicates that the trajectory is lower, than it should be (i.e., passes through denser layers of the atmosphere). In this case, it is necessary to reduce the roll angle (e.g., make it equal to zero) and then the upward side force will correct the trajectory. Thus, the signals that change the roll angle are supplied by the converter after the latter has compared the actual and programmed decelerations for any moment of time. Controlled re-entry is of special importance when the spacecraft approaches the atmosphere at the second cosmic velocity, as may be the case on returning from the Moon or Mars. At an insufficiently steep re-entry and in the absence of a system of descent control, the re-entry body is liable to leave the atmosphere again since the Earth's atmosphere is spherical and a tangent trajectory brings the re-entry body rapidly beyond the atmosphere. Such a situation leads to an inevitable loss of the spacecraft due to lack of power resources for returning it to the Earth. On the other hand, too steep a re-entry into the atmosphere produces excessive overloads that the crew will be unable to bear. In both cases, these difficulties can be overcome by controlled re-entry. If the deviation of the re-entry angle from the computed value is slight, this can be eliminated by moving with a roll of 180° (in the first case) or 0° (in the second case). In the above example, a 90° roll is evidently required for moving along the computed trajectory. This causes a certain side drift that can always be taken into account beforehand.

FLIGHT PATH. See ORBIT.

FLIGHT TESTING OF ROCKET ENGINE. Tests of a rocket engine in flight, the concluding stage in the testing program of a newly developed rocket engine. During the flight testing the engine performance data are measured by space-borne instruments and transmitted through telemetry radio channels to ground stations with their subsequent decyphering. To do so, the engine is furnished with the necessary telemetry pickups. Flight tests are also used for percentage tests of batch-produced rockets.

FLOATED GYROSCOPE. A gyro that is suspended by means of a float immersed in a liquid whose density is equal to the mean density of the float. Thus, the sensitive axes are relieved of the float weight and inertial forces arising in accelerated motion. As a result, the floated gyroscope has a small inherent drift and an improved resistance to the effect of vibration and overloads during the rocket engine operation.

FLOW INTENSITY. The value equal to the propellant flow rate per unit of area of the combustion chamber cross section.

FLUORINE, liquid, F_2. A cryogenic oxidizer for liquid-propellant engines. A yellow, low-boiling, pungent liquid; density, 1.51 g/cm^3 at —187°C; m.p. —188°C; b.p. —218°C. Liquid fluorine is the most effective oxidizer and therefore of great importance for future use. Propellants based on liquid fluorine produce the highest specific impulse and have a high density. Chemically stable. The products of combustion of fluorine-containing propellants are poisonous. Fluorine is one of the most active oxidizers; with fuels it forms self-igniting propellants. Reacts vigorously with most substances, many of which ignite in it spontaneously. On the surface of some metals (e.g., Monel, nickel, copper and their alloys, aluminium alloys) it forms a durable fluoride film protecting the metal from destruction. The inflammation of metals in liquid fluorine is brought about by friction, impurities, and a high flow rate of the oxidizer. Used in engines now in the stage of development in combination with liquid hydrogen and other fuels. Liquid fluorine was supposed to be used in a tripropellant in combination with hydrogen and lithium. It was first proposed by F. A. Tsander in 1932, and the mixture of LOX and liquid fluorine, in GDL in 1933. The high chemical aggressiveness and toxicity of liquid fluorine and the high temperature, exceeding 4500°C of the combustion products in the thrust chamber of a liquid-propellant engines, makes it necessary to solve a number of problems prior to adoption of this oxidizer in rocket and space technology.

FLUORINE MONOXIDE, liquid (difluorine monoxide, oxygen difluoride), OF_2. A cryogenic oxidizer for liquid-propellant engines. A low-boiling yellowish liquid with an unpleasant odour; density, 1.52 g/cm^3 at —145.3°C; b.p., —144.9°C; m.p., —233.9°C. Very poisonous, the combustion products are also poisonous. It is less reactive than liquid fluorine, not so aggressive and corrosive, but more poisonous. In the liquid state its chemical stability is satisfactory; in the gaseous state it forms explosive mixtures with water vapours (mixtures with humid air are explosive). Propellants with liquid fluorine monoxide are less effective than those with fluorine, but more so than those with oxygen. Fluorine and fluorine monoxide in combination with liquid hydrogen produce practically the same maximum specific impulse, but the propellant with fluorine monoxide is 25% lighter in weight. Has been studied theoretically and tested experimentally in GDL-OKB (at the beginning of the 1950s) in laboratory engines in combination with various fuels. Has not been put to use; its production is more complicated than that of fluorine.

FLUORINE OXIDIZERS. A group of oxidizers for rocket propellants containing FLUORINE (elementary or as a compound); liquid fluorine is the most effective of existing oxidizers for liquid-propellant engines; the propellants

formed with it produce the highest SPECIFIC IMPULSE and have a high density. Fluorine and fluorine monoxide, the cryogenic oxidizers are in the stage of detailed study; the rest of the fluorine oxidizers are substantially inferior to fluorine and fluorine monoxide as concerns the specific impulse of the propellant based on them. The possibility of using chlorine trifluoride, chlorine pentafluoride, bromine pentafluoride, nitrogen trifluoride, hydrazine tetrafluoride and other fluorides is also under study. Other oxygen fluorides are known (F_2O_2, F_2O_3 and others), which are unstable in the liquid state and decompose before the boiling point is reached. F_2O_3 is intended for use as an additive to liquid oxygen to obtain hypergolic propellants. More complex oxidizers have been investigated, containing chlorine in addition to fluorine and oxygen, for example, $FClO_3$ and $FClO_4$. Fluorine oxidizers, as a rule, are toxic, chemically active, and of a considerable density in the liquid state (1.5—2.5 g/cm^3). The common defficiency of all fluorine oxidizers is the formation of toxic, corrosive hydrogen fluoride in the combustion products.

FOOD RECYCLING. Food recovery from the metabolic by-products of human beings and the BIOCOMPLEX to provide adequate nourishment for the crew during space flights lasting several years and more, as well as on planetary stations. Food recycling is achieved by means of a LSS based on RECYCLING OF SUBSTANCES. The most effective cycle is one that includes unicellular algae, higher plants, eatable animals, and man.

Algae can be used for air recovery, nourishment of animals and man as well as for utilization of metabolic by-products after preliminary treatment. Practically, the entire algae biomass can be used to feed animals and human beings. However, unicellular algae have fetal membranes which are hard to digest, and this makes it difficult to use them for human nourishment. Another disadvantage is the high content of chlorophyll. Methods have been developed for destroying the cell walls and extracting the pigments, which substantially increase the value of these algae as food. The amount of recovered algae biomass in the daily diet should not exceed 10—15%.

The higher plants constituting a sub-system of the biological LSS are also capable of effecting air and water recovery and utilization of metabolic by-products after preliminary treatment. The best plants for a space greenhouse are potatoes, tomatoes, the various sorts of cabbage, carrots, as well as such vitamin-rich plants as spinach, lettuce and onions. Such a greenhouse is practically indispensable if long-duration space trips are to be carried out mainly with the utilization of stocks of provision. It will be the source of cellulose and mineral substances.

For the purpose of satisfying the need for nutritively adequate animal proteins some animals are included in the food recovery sub-system of the biological LSS. They are chosen according to requirements for adequateness of the proteins obtained, utilization of plants (algae, humanly indigestible parts of greenhouse plants) and metabolic by-products of human beings, absence or a minimum quantity of inedible constituents, simplicity and dependability of cultivation and rapid growth in the least possible space; resistance to the action of adverse factors of space flight. Lower animals, including microbial flora, hydrogen bacteria and others, comply with these

requirements. The possibility of using them as food for spacemen is still being carefully studied; specimens of zooplankton of fresh water and sea, fish, and land invertebrates are also being investigated. On space stations on other planets, where minimum space and limited consumption of oxygen are no longer a necessity, it is feasible to make use of poultry, rabbits, and other higher animals. Hens can be fed with unicellular algae, the humanly indigestible parts of higher plants, the waste from man's food and human metabolic by-products, as well as waste products from the hens themselves. A method of forced feeding of hens has been developed which can prove to be of great importance under conditions of weightlessness or reduced gravitation; they can be kept in a limited space (in cages); reproduction of progeny is possible by means of incubation.

Food recycling

Food recovery in the physicochemical LSS consists in the synthesis of the basic food materials from the metabolic by-products of human beings and the biological complex. Only monocompounds, such as amino acids, fatty acids, glucose can be practically synthesized; circulation of mineral substances can also be achieved, whereas vitamins must be taken along from Earth or obtained in the space greenhouse. The use of synthetic chemical food in long-term experiments, including tests for survival, reproduction and lactation in several generations, has shown that it ensures normal growth, life span and reproduction of the test animals (rats). Clinical investigations carried out on human beings have shown that a diet consisting of chemically pure (monocompounds) foodstuffs assures normal body weight, rapidly replenishes the supply of proteins in case of deficiency, and causes no deviations in the functioning of the liver and the kidneys. Clinical investigations have been made to ascertain the suitability of chemical diets for human beings under conditions of prolonged space flight, using for this purpose liquid chemical food consisting of complete set of amino acids, balanced with the required amounts of glucose, salts of unsaturated fatty acids and all the necessary vitamins and mineral salts; the daily calorific value of the diet was equal to 2700 kcal. The data obtained in these investigations showed that such diets are adequate for nourishment of human beings during long periods of time, and that they do not involve any unfavourable physiological or biochemical reactions and are not toxic. Chemical foods possess a number of advantages: high calorific value at maximum compactness; complete solubility, permitting food consumption in a liquid state under conditions when solids cannot be used; small amount of wastes which can be easily eliminated; good storability; ease of composing the diet permitting necessary changes in the proportion of amino acids and other components which makes it possible to compose the diet in accordance with the individual requirements of the man in space flight conditions. The significant disadvantages are: negative psychological reaction; the absence of factors stimulating peristalsis and constituting, at the same time, the source of normal development of the microflora of the intestines (cellulose); prolonged exclusion from the digestive process of enzymes responsible for hydrolysis of proteins, fats and polysaccharides. Possibly this problem could be solved by combining the use of chemical food rations with that of products of a minimum greenhouse. One of the prospective means of solving the food problem consists

in the combination of biological and physicochemical synthesis of foodstuffs and storage, on board the spaceship, of certain biologically important indispensable compounds used in microquantities.

FORBUSH EFFECT. A decrease, in the period of geomagnetic storms, in the intensity of primary cosmic rays arriving at the Earth. Thus, some usually most violent, solar flares produce corpuscular fluxes. As a result, the Earth, about 2 days after the flare, gets into the cloud of solar plasma. The latter carries with it the "frozen" magnetic field which traps many particles of cosmic rays and prevents them from getting onto the Earth.

FORCED VIBRATION in rocket engine. Oscillations appearing in a system under the influence of periodical changes of an external force (stimulus). The nature and, in particular, the amplitude of forced vibration are determined by the nature of the stimulus, the parameters of the vibratory system, etc. The forced vibration is transient, or non-periodic, when the stimulus effect begins. A certain period of time has to pass for it to become periodic with the frequency equal to that of the stimulus changes. In a vibratory system, the higher are the damping characteristics, the shorter is the period of transient vibration. The phenomenon of resonance appears when the frequency of the stimulus coincides with the natural frequency of the vibratory system. Forced vibration of gas pressure in the combustion chamber of a liquid-propellant engine is observed, for instance, during longitudinal oscillations of the rocket airframe or of the head of liquid at the inlet of the rocket engine.

FRAME. A structural element of an airframe, that supports the propellant tanks, accepts radial loads, and serves to improve structural rigidity of the airframe. It is a thin-wall ring of a specific cross section.

FREE FLIGHT. The motion of a spacecraft beyond the atmosphere after thrust cut-off, due solely to the action of the forces of attraction of the Sun and planets. Spacecraft in free flight obey the laws of celestial mechanics and their flight paths can be pre-computed and forecast with a high degree of accuracy.

FREE GYROSCOPE. An astatic gyro which has 3 degrees of freedom relative to its base. This is a gyro whose axis is not maintained continuously or re-established periodically in the preset angular position by a correction system. The initial angular position of the gyro changes gradually due to its DRIFT. Therefore, a free gyro can serve as a position pickoff only in cases when it is used for a relatively short period of time (for example, in systems of spacecraft ANGULAR STABILIZATION at short-time operation of the rocket engine).

FREEZE DRYING (molecular drying). Dehydration of moisture-containing solid products and materials by sublimating water at low temperatures in vacuum. Freeze drying is used in LSS as one of the prospective methods for water recovery from moisture-containing materials. By freezing urine to a temperature of $-5°$ to $-10°$C in a vacuum of $1 \cdot 10^{-3}$ mm Hg, only water molecules are sublimated. Water is then collected by freezing out at still lower temperatures in a condenser. The disadvantage of the freeze-drying method is the large dimensions of the installation because the process must be conducted at low pressures and temperatures.

FRENCH EARTH SATELLITE. The *A-1* was France's first artificial Earth satellite. It was launched on November 26, 1965, by a French *Diamant* launch

vehicle into an orbit with an apogee of ~1800 km. This experimental spacecraft weighed 42 kg and was not oriented in flight; its energy supply was provided by chemical sources; its operational life was about 2 days. The *FR-1* satellite, weighing ~60 kg, was sent into orbit on December 6, 1965, by an American *Scout* launch vehicle to study the ionosphere and propagation of very-low-frequency radiation. The satellite was spin stabilized and energized by solar batteries. On February 17, 1966, a French *Diamant* launch vehicle injected the *Diapason-1* satellite, to be followed by *Diadème-1* and *Diadème-2* satellites on February 8 and 15, 1967, respectively. The *Diadèmes* are designed for geodetic measurements and study of the Earth's gravitational field. The weight of each satellite was ~23 kg, and dia 0.5 m; in-flight orientation was by means of a magnetic system. The surfaces of the body and of the panels of solar batteries mounted 144 reflectors to return signals from ground-based lasers (for precise location of the satellite in orbit).

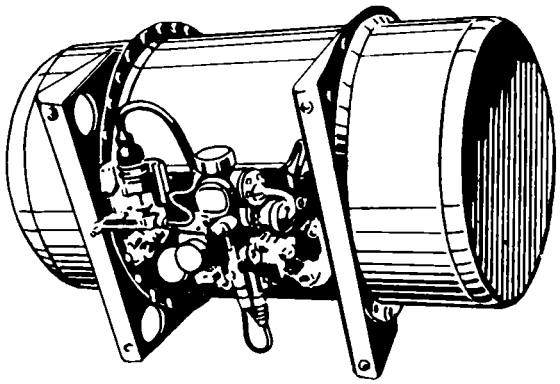
FRENCH GUIANA RANGE. A French missile range now under construction on the coast of French Guiana between the towns of Sinnamarie and Kourou. When completed, the range will occupy 1000 km². The first stage of construction will comprise launch complexes for the *Diamant* vehicles and for space probes. The French Guiana Range is situated almost on the equator (5° N.L.), which is favourable for launching satellites into equatorial orbits. The first launching of the *Diamant* vehicle is scheduled for 1970. A *Véronique* probe was first launched from this range in April, 1968. The estimated cost of the first stage of construction is $60 million. A space and nuclear research range is also under construction on Mangareva Island in the Pacific (1600 km SW of Tahiti).

FRENCH ROCKET ENGINES. Production-type liquid-propellant engine *SEPR-844* (thrust, 1.7 t; burning time, 80 s; weight, 90 kg; propellant, NITRIC ACID and KEROSENE), was designed as a rocket-assisted take-off unit for the *Mirage IIIE* fighter; another batch-produced liquid-propellant engine SNECMA *Vexin* (thrust, 31 t; specific impulse at ground, 203 s; burning time, 88 s; propellant, nitric acid and TURPENTINE, pressure-fed) powers the 1st stage of the *Diamant* rocket. The experimental four-chamber liquid-propellant rocket engine *SEPR* with a thrust of 4·1.5 t is being developed for the *Coralie* rocket which constitutes the 2nd stage of the 3-stage space launch vehicle *Europa-1* (*ELDO-A*); it will burn LOX and liquid hydrogen. This rocket underwent flight tests in 1966 with an engine firing nitrogen tetroxide and unsymmetrical dimethyl hydrazine. Among the batch-produced solid-propellant engines, there are the *SEPR-739* (thrust, 16.6 t; burning time, 17.5 s; length, 4.69 m; weight, 1.56 t; designed for the 1st stage of the research rocket *Bérénice*) and the *SEREB* (thrust, 19 t; burning time 18 s for the rockets *Agate* and *Rubis*). The experimental solid engine *SEPR-P-10* (thrust, 43 t; burning time, 62 s; weight, 9.5 t) is designed for the rocket *VE-112*. Also being developed is a hybrid rocket engine *ONERA* with a thrust of 1—0.2 t firing a solid fuel and LOX. It weighs 77 kg and has underwent flight tests.

FUEL. The component of a rocket propellant which is oxidized (burnt) in chemical reaction with the oxidizer. Liquid fuels are subdivided into hydrocarbons (KEROSENE, TURPENTINE, etc.), nitrogen hydrides (AMMONIA,

HYDRAZINE, etc.), hydrogen borons (diboran, PENTABORAN, etc.), their derivatives (alcohols, esters, ethers, AMINES, MONOMETHYL HYDRAZINE and DIMETHYL HYDRAZINE, nitro compounds, etc.), liquid HYDROGEN and metal-containing fuels (organometallic compounds, SUSPENSIONS, etc.). Of potential importance is the use of light metals, such as beryllium, lithium, aluminium and some of their hydrides, because of their high HEATING CAPACITY.

FUEL CELL. A source of electric power used in spacecraft. Fuel cells produce electric energy as a result of an electrochemical process between two working fluids such as hydrogen and oxygen. The oxygen and the hydrogen chambers of such a cell are separated by a porous ion-exchange membrane through which hydrogen ions (cations) pass to combine with oxygen ions and form water while the electrons find their way to the electrodes to set up a usable difference of electrical potentials. The hydrogen and oxygen are stored on board in the liquified state. A fuel cell power system has a watthour capacity 4—5 times that of a comparable chemical battery system. Besides, the water formed in the cells may be utilized in the LSS.



Fuel cell battery of *Gemini* spacecraft (in container).

FUEL FEEDING. Delivery of liquid propellants from tanks into the combustion (heating) chamber of rocket engines (see PRESSURE FEEDING OF PROPELLANT, PUMP FEED). Methods are being developed for feeding solid components of propellants.

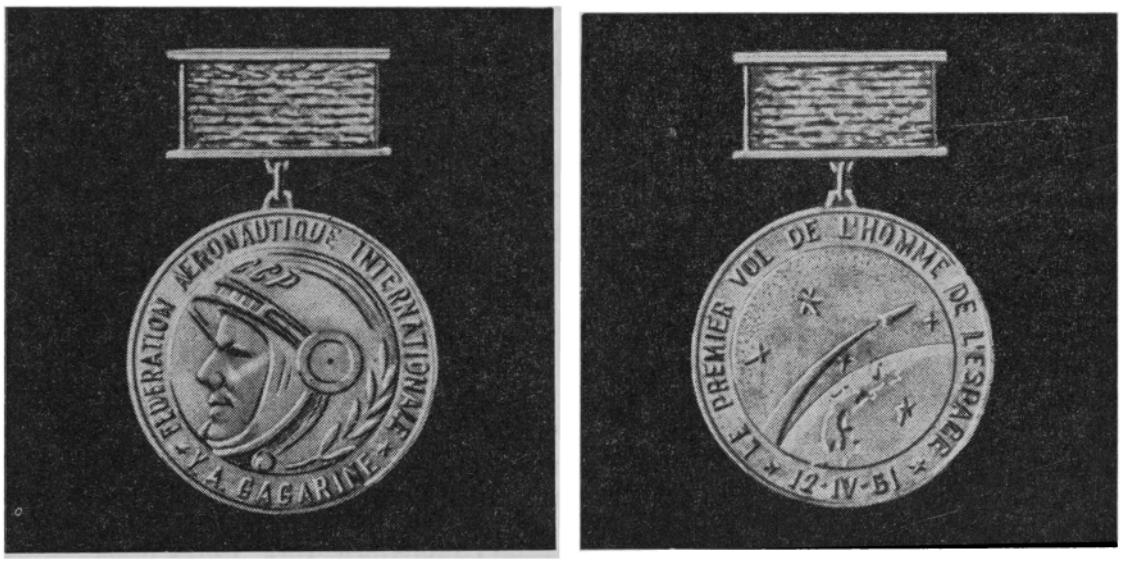
FUEL HOSES. Flexible pipelines used for transporting liquid propellants. The hoses serve for coupling the filling pipelines with the valves of propellant tanks, the outlet necks of mobile servicers with supply valves of propellant terminals. Hoses for handling non-aggressive propellants are made of cotton fabric with internal rubber protection. Two metal coils are provided for making the hoses resistant to external and internal pressure. Sylphon metallic hoses with an outer braiding are used for handling cryogenic and aggressive propellants.

FUELLING VALVE. See PROPELLANT-LOADING FITTINGS.

FYODOROV, Alexander Petrovich (late 19th century). Russian inventor. In 1896 published a book in St. Petersbourg entitled *Novy printsip vozdukhoplavaniya* (*A New Principle of Aeronautics*) where he described a rocket craft for space travel without supporting media. Steam, compressed air, or carbon dioxide were proposed as working fluids. A crater on the far side of the Moon has been named in his honour.

GAGARIN, Yuri Alekseyevich (born 1934, Klushino, Gzhatsk Districts, Smolensk Region; died 1968). Pilot-cosmonaut of the USSR, the first man to fly in space. Hero of the Soviet Union; deputy to the Supreme Soviet of the USSR; colonel; member of CPSU since 1960. Finished a foundry workers vocational school near Moscow (1951), the Saratov industrial training secondary technical school (1955). At the same time he graduated from an airclub flying school. After this he attended and then graduated (1957) from the 1st Chkalov Air Force Pilots School. In 1968 he graduated from the Air Force Engineering Academy (Moscow). On April 12, 1961, Gagarin, aboard the spaceship *Vostok*, made his round-the-Earth orbital flight lasting 1 h 48 min. Yuri A. Gagarin died on March 27, 1968, in an accident during an aircraft training flight. A crater on the far side of the Moon has been named in his honour.

GAGARIN MEDAL. A gold medal instituted in 1968 in honour of Yuri Alekseyevich Gagarin. The Fédération Aéronautique Internationale (FAI) annually awards the Gagarin medal to spacemen who make distinguishing contributions towards the peaceful conquest of space.



Gagarin medal

GALABERT, Henri (1914). French industrialist. Instituted an international award for outstanding achievements in space science and exploration (1958). Among the winners of this prize are Yu. A. Gagarin, V. V. Nikolayeva-Tereshkova, A. A. Sternfeld, A. G. Masevich, G. Glenn, W. von Braun, N. Armstrong, E. Aldrin, and M. Collins.

GALACTIC NEBULAE. Concentrations of gas and dust in interstellar space. The following types of galactic nebulae are known: (a) planetary nebulae—comparatively small, usually circular discs with a central star; mean density of the gas is $\sim 10^{-20}$ g/cm^3; the temperature is approx. 10,000°K and the mass is $\sim 10^{-5}$ of the solar mass; these nebulae were formed in the process

of relatively tranquil expansion of the central star shell; (b) diffuse emission nebulae—larger structures of irregular form; their mass exceeds that of the Sun many hundreds of times; the density and temperature are lower than in planetary nebulae; they are located near clusters of hot stars; (c) dark and reflective dust nebulae—the densest clouds of cosmic dust; they can be observed because they reflect the light of nearby stars or obscure the light of background stars; (d) the remnants of Supernovae outbursts—shells expanding at high velocities from their mother-stars after powerful outbursts of the latter; these stars belong to a specific type; their mass ranges from 0.1 to several solar masses. A knowledge of stellar evolution is gained from the study of galactic nebulae.

GALAXY. A complex system of stars, gas and dust of varying age, origin and composition. Part of the stars and gas and almost all of the dust are concentrated near the galactic plane in a region resembling a flat lens. The principal part of our Galaxy that we see in the sky is called the Milky Way. A densy globular cluster of massive stars and a certain amount of gas form the nucleus of the Galaxy. The center of this nucleus is much denser than other parts of the Galaxy and is rich in gas in a highly turbulent state. The radius of the Galaxy is about 14,000 parsec, the estimated number of stars is of the order of 10^{11}, and the total mass is about 10^{11} times the solar mass. Gas and dust probably comprise a small part of the total mass of the Galaxy. Our Sun is about 10,000 parsec from the center of the Galaxy. The formation of stars in our Galaxy still continues. The old galactic population forms the globular part of this stellar system, while the young population forms the flattened part that tends towards the plane of the Galaxy. The galactic orbits of globular star clusters are ellipses of large eccentricity and are variously inclined to the galactic plane.

Stars of the flattened part move in a fairly circular orbit of very low inclination. The youngest stars and stellar clusters form the spiral arms that are typical of our Galaxy, as well as of other Galaxies.

GANSWINDT, Herman (1856—1934). German inventor. Suggested a design of rocket-propelled spacecraft for interplanetary travel with propulsion by intermittently exploding dynamite cartridges (1893). A crater on the far side of the Moon has been named in his honour.

GAS ANALYSER. An automatic device for performing the quantitative analysis of gas composition in the spaceship cabin, generally by oxygen, carbon dioxide and water vapour content. The analysis results are usually indicated by a special device on the cockpit instrument panel and radio communicated to the Earth by telemetry system. The gas analyser can be used for automatic control of the system of BIOLOGICAL AIR REGENERATION. Electrochemical gas analysers are based on the principle of the varying resistance of oxidized metal depending on the concentration of oxygen in the sealed cabin atmosphere. Magnetic gas

analysers compare the permeance of the gas under test with that of a standard reference gas.

GAS BAFFLE. A wedge-shaped element of the flame deflector or of the gas exhaust system of a launcher, intended for dividing the engine efflux into a number of streams which are then directed to the zones where they are harmless for the launch vehicle and the equipment. Sometimes the gas baffles protect certain elements of the launcher (e.g., jacks, supports, hoisting and swivelling machinery, etc.) against direct jet impingement.

GAS DYNAMICS. The scientific discipline that studies the motion of gases at high velocities (with due account for compressibility); serves as the theoretical basis for analysing the flow of the WORKING FLUID in nozzles and other units of rocket engines, supersonic flight in atmosphere, etc.

GAS DYNAMICS LABORATORY (GDL). The first Soviet rocket research and development organization. It was established under military auspices in Moscow in 1921 at the initiative of N. I. TIKHOMIROV with the aim of developing missiles firing smokeless gunpowder. Some of the work was conducted in Leningrad. In 1927 it finally moved to Leningrad and was given its permanent name: Gas Dynamics Laboratory. By that time the GDL had created a smokeless gunpowder based on a non-volatile solvent (trotyl pyroxylin) with a big web thickness. In the period of 1927—1933, the GDL developed solid rocket assists for the take-off of light and heavy aircraft (*Y-1*, *TB-1*, and other planes), and missiles of various calibre and destination, including airborne rockets. After some further development by the ROCKET RESEARCH INSTITUTE, they were used during the war of 1941—1945 in the *Katyusha* rocket launchers. Major creative participants in these developments were N. I. Tikhomirov, V. A. Artemyev, B. S. PETROPAVLOVSKY, G. E. LANGEMAK, and others.

On May 15, 1929, the GDL established a group (subsequently a department) to develop the world's first electrical rocket engine and the Soviet first liquid-propellant engines. A family of liquid-propellant engines, beginning from the *OPM* and *OPM-1* to *OPM-52* delivering a thrust of up to 300 kg, was developed in the period of 1930—1933. A number of oxidizers (nitric acid and its solutions with nitrogen tetroxide, perchloric acid, tetranitromethane, and hydrogen peroxide) and fuels (berillium, berillium-oxygen-hydrogen tripropellant, etc.) were suggested for the first time in 1930 for use in rocket propellants; zirconium dioxide for heat insulation of combustion chambers and the bell-shaped nozzle were developed in the same year. The developments achieved in 1931 were a hypergolic propellant, chemical ignition, and the gimbaled engine. Some 50 bench firings of liquid-propellant engines were held in 1931. Besides the rocket engines, the Laboratory developed and tested in 1931—1932 piston pumps for propellant feeding, that were energized by gas bled from the combustion chamber of the rocket engine, and in 1933 it designed a turbopump unit with centrifugal pumps for an engine developing 300 kg of thrust. M. N. TUKHACHEVSKY, the Armament Chief of the Red Army, to whom the GDL was subordinated, was present at a test of a liquid-propellant engine, and wrote to the Commander of the Military Engineering Academy of the Red Army in 1932:

"The liquid jet engine designed lately at te GDL will be of great importance in the future".

Gas Dynamics Laboratory

V. P. Vetchinkin, who witnessed the testing of the OPM-9 engine firing an oxygen-gasoline propellant at the GDL in 1932, wrote: "The major part of the work necessary for the creation of a rocket, i.e. design of a reaction motor burning a liquid propellant, has been done at the GDL.... Viewed from this aspect, the GLD's achievements should be termed as brilliant". In the summer of 1932 and again in January, 1933, the GDL was visited by the leaders of the Group for Study of Reactive Motion set up in June 1932: S.P. Korolev, F.A. Tsander, M. K. Tikhonravov, J. A. Pobedonostsev, and others. They were shown captive firings of liquid-propellant engines. This was the beginning of collaboration between the workers of the GDL and the GIRD. For over 30 years. the engines designed by talented engineers trained at the Leningrad Gas Dynamics Laboratory have been mounted in all the vehicles of Korolev's design: winged rockets, aircraft power units, long-range continental and intercontinental missiles, powerful meteorological and geophysical rockets, and on all the space vehicles.

Taking part in designing the electrical rocket engines and liquid-propellant engines, under the supervision of the designer of engines in the Laboratory, were the engineers and technicians A. L. Maly, V. I. Serov, Y. N. Kuzmin, I. I. Kulagin, Y. S. Petrov, P. I. Minayev, B. A. Kutkin, V. P. Yukov, N. G. Chernyshev, V. A. Timofeyev, N. M. Mukhin, I. M. Pankin, and others. The GDL's group for the development and testing of electrical and liquid-propellant engines was housed in 1929—30 in Leningrad's Electro-Physical Institute, in 1930—33 at the Artillery Proving Ground in Rzhevka (near Leningrad), in 1932—33 in the Chief Admiralty building and the Ioannov Ravelin of the Peter-and-Paul Fortress in Leningrad.

Late in 1933 the Gas Dynamics Laboratory and the Group for the Study of Reactive Motion were merged into the Rocket Research Institute stationed in Moskow. In the period of 1934—38 the group of specialists on liquid-propellant engines, trained at the GDL, developed at the Institute a series of experimental engines from *OPM-53* to *OPM-102* with nitric acid and tetranitro methane as oxidizers and the first Soviet gas generator *ГГ-1* which worked for hours on a nitric acid + kerosene propellant with water at a temperature of 580°C and a pressure of 25 at, producing a neutral pure gas (official tests were held in 1937). In 1939 the head of the work on liquid-propellant engines who began the experiments at the GDL in 1929—33 and continued them at the RNII in 1934—38, created an independent body which later, in 1941, grew into the OKB, Experimental Design Office for liquid-propellant engines. In the 1940's the OKB produced a family of aircraft liquid-propellant engines, *РД-1* to *РД-3*. The Chief Engine Designer's deputies were: S. P. Korolev (deputy for flight tests in 1942—46), G. S. Zhiritsky, D. D. Sevruk, V. A. Vitka, N. N. Artamonov, G. F. Firsov, and others.

Developed by the OKB in 1947—68 were scores of high-power liquid-propellant engines which were employed on rockets of various designations.

Memorial plaque mounted on building of Ioannov Ravelin in Peter-and-Paul Fortress, Leningrad.

Gas generator

These engines have powered most Soviet continental and intercontinental missiles and all the geophysical and space rockets launched in the USSR up to 1969.

In connection with the 40th anniversary of the GDL—OKB (1929—1969) memorial plaques were unveiled on the buildings where the GDL was housed in the 30's, the Admiralty and the Ioannov Ravelin of the Peter-and-Paul Fortress.

The text reads:

> In 1932—1933, here, in the Ioannov Ravelin, were situated the testing stands and mechanical workshops of the first Soviet experimental design office for developing rocket engines, the Gas Dynamics Laboratory (GDL) sponsored by the Military Research Committee of the Revolutionary War Council of the USSR.
>
> Here
>
> were conducted the static tests of the world's first electrothermal rocket engine and first Soviet liquid-propellant rocket engine developed at the GDL in 1929—1933.
>
> The GDL laid the foundations of Soviet rocket engineering. The twice-decorated staff of the experimental design office, trained at the GDL, created the powerful engines of the launch vehicles that injected into orbits artificial satellites of the Earth, the Moon, and the Sun; sent automatic stations to the Moon, Venus and Mars and put into space the manned *Vostok*, *Voskhod*, and *Soyuz* spaceships.

In appreciation of the contribution made by the GDL—OKB to the development of rocket-space engineering, a 1100-km long chain of craters on the far side of the Moon was named after the Gas Dynamics Laboratory, and several lunar craters were named after staff members of the GDL—OKB.

GAS GENERATOR. A unit of a liquid-propellant engine used to provide heated gas (at a temperature of 200°—900°C) generated by combustion or decomposition (thermal, catalytical, etc.) of the propellant or its components, the gas serving as a working fluid to drive the turbopump, to pressurize the propellant tanks, to actuate the control system, etc. Most frequently used in gas generators is the prime propellant with an excess-of-oxidizing-elements coefficient considerably different from 1. Sometimes one of the components of the prime propellant (oxidizer or fuel, e.g., unsymmetrical dimethyl hydrazine) is decomposed in the gas generator. Auxiliary rocket propellants may also be used. Depending on the composition of the gas produced, the gas generators are classified as reducing and oxidizing ones. The main components of a gas generator are the injector system and its body.

GASIFICATION. The process of converting a liquid into a gas, employed at space centres or in spaceships. Liquified gases can be conveniently stored and transported, since the volume and weight of the containers required for a given weight quantity of gas is considerably less than for storage and transportation of the same gas when it is pressurized, and at the place of consumption (space centres) the liquid is reconverted into gas in special gasifiers. The bottles of launch vehicles are charged with gaseous nitrogen; nitrogen is obtained as a liquid in the air-separation units of the gas-filling station and is then converted into gas in gasifiers.

GASIFIER. An apparatus for storing liquid oxygen (nitrogen, hydrogen, etc.) and its conversion into gas of the required pressure. The apparatus is used in the LSS and other systems of a spaceship. A gasifier usually consists of a Dewar flask, evaporator, controls for maintaining the design working pressure, and a gas meter. In the gasifier of the *Apollo* spacecraft LOX is stored in single-phase state at supercritical pressure.

GAS RELIEF. The reduction of pressure in a propellant container at a space centre, achieved by releasing the excessive gas through a vent or a drain safety valve. The gas relief can be operated either positively or automatically. Positive gas relief is realized by sending the signal to open the vent valve after the process of propellant loading is over. In the case of overpressure, the automatic gas relief vents the gas through a drain safety valve that opens automatically at a predetermined pressure level.

GAS SEPARATOR. A device built into the propellant loading manifold of a space centre and intended for separation of gas inclusions from propellants. This is necessary for accurately measuring the quantity of the propellant loaded, as well as for normal functioning of the centrifugal fuelling pumps; therefore, gas separators are installed before volumetric flowmeters and pumping plants. Gases are separated by means of fountain blowing, by slowing down the flow of the propellant in large volume ducts, or by centrifugal forces; in the 1st and the 2nd cases, gas bubbles rise to the surface of small streams or of the slowly flowing liquid, while in the 3rd case the liquid is fed tangentially into the gas separator shell where it is subjected to centrifugal forces and, being heavier than the gases, spreads over the periphery of the shell, while the gases are concentrated in the centre of the shell and bleeded therefrom into the atmosphere or, if the gases are hazardous, into special containers.

GAS SERVICER. A mobile unit for charging compressed air into the launch vehicle bottles or various items of ground equipment at the space centre. It comprises a receiver unit, a group of compressed-gas bottles, a system of pneumatic valves, pressure reducer valves, high-pressure pipes, dispensing and charging panels, and a panel for controlling the gas-charging process. The gas servicer is charged with compressed gas at the gas supply station and delivers it to the launch site.

GAS-TIGHT HATCH. A hatch designed with packing round its perimeter and mounted in the PRESSURIZED COMPARTMENT of a spaceship. In some cases this hatch is fitted with a quick-release mechanism, e.g., to facilitate exit of the spaceman into free space while in orbit or escape from the spaceship by ejection, etc.

GAS VANES. Shaped swivelling plates placed in the jet stream at the exhaust end of a rocket nozzle to deflect the jet and thereby control the thrust vector. Four gas vanes ensure the pitch, roll and yaw control of a rocket in flight. They are made from a refractory material, e.g., graphite. Gas vanes were suggested by K. E. TSIOLKOVSKY.

GDL. See GAS DYNAMICS LABORATORY.

GELLED PROPELLANT. A viscous, jelly-like liquid consisting of a fuel with a high calorific value, a solid oxidizer, metallic powders, and a gelatinizing agent. It can be a THIXOTROPIC PROPELLANT.

GEMINI. The name of a type of American two-seater spaceship designed for flights in near-Earth orbits, and the name of its development and flight program. The *Gemini* spaceship weighs 3.5 t. It consists of a pressurized re-entry capsule which accommodates 2 astronauts and a separable unpressurized compartment with equipment and retro-engines. The capsule is 2.25 m in dia and 5.7 m long. The *Gemini* spaceship is provided with equipment and rocket engines to perform manoeuvres in order to approach other spacecraft in orbit. The LSS is designed for 14 days; the spaceborne equipment is powered from fuel cells. Provisions are made for splashdown only. The 1st flight of the *Gemini-3* spaceship with astronauts V. Grissom and J. Young on board was accomplished on March 23, 1965. The *Gemini-4* spaceship was launched on June 3, 1965 (astronauts J. McDivitt and E. White). In the course of the flight, White spent 20 min outside the capsule, in open space (this happened $2^1/_2$ months after the world's first space walk made by the Soviet cosmonaut A. A. Leonov). The *Gemini-5* spaceship was blasted off on August 21, 1965 (astronauts G. Cooper and C. Conrad);

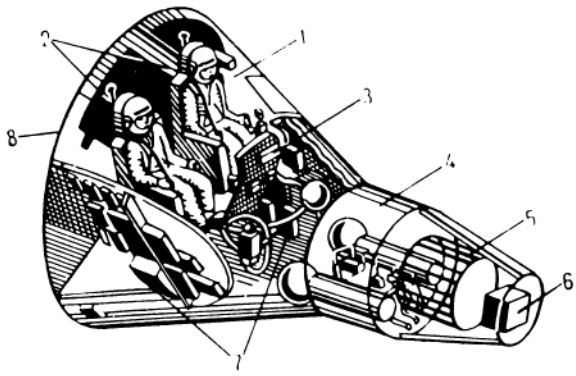
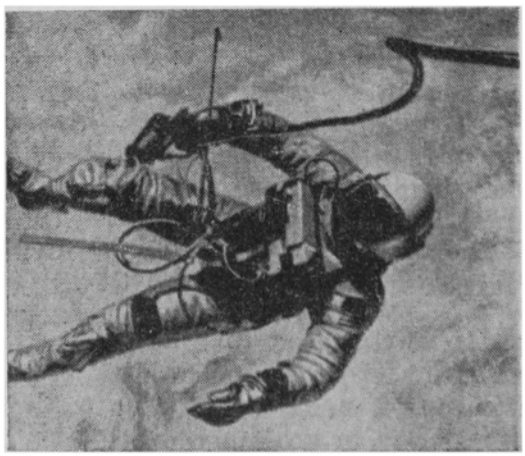
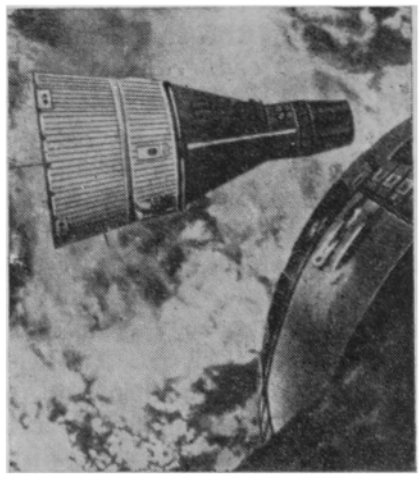


Diagram of re-entry capsule of *Gemini* spaceship.

1—sealed capsule; *2*—astronaut's seats; *3*—control console and instrument panels; *4*—compartment of attitude control system; *5*—parachute container; *6*—rendezvous radar; *7*—space-borne instruments and equipment; *8*—heat shield.



The American astronaut E. White on "space walk" during *Gemini-4* flight.



Gemini spaceships in rendezvous flight.

it circled the Earth for 190 h. The *Gemini-7* spaceship lifted off on December 4, 1965 (astronauts F. Borman and J. Lovell); the spaceship stayed in orbit for 330 h (till now it is the longest stay of man in space). During this flight the *Gemini-7* spaceship approached in orbit *Gemini-6* (astronauts W. Schirra and T. Stafford) launched on December 15, 1965. The spaceship *Gemini-8* was sent into orbit on March 16, 1966 (astronauts N. Armstrong and D. Scott); during the flight, the docking with the already-orbiting *Agena* target vehicle was accomplished, after which the controllability of the spaceship was lost and an emergency landing was effected from the 6th orbit. *Gemini-9* roared off on June 3, 1966 (astronauts T. Stafford and E. Cernan); during this flight the spaceship approached in orbit the *ATDA* target satellite. Astronaut E. Cernan made a 2-hour space walk. The *Gemini-10* spaceship lifted off on July 18, 1966 (astronauts J. Young and M. Collins). *Gemini-11* was placed in a round-the-Earth orbit on September 12, 1966 (astronauts C. Conrad and R. Gordon); the maximum flight altitude was 1370 km. *Gemini-12* roared into space on November 11, 1966 (astronauts J. Lovell and E. Aldrin); in the last 3 flights the docking of the *Gemini* spaceship with *Agena* target vehicle was accomplished and space walks by M. Collins, R. Gordon, and E. Aldrin were taken.

GEOCENTRIC COORDINATES. Coordinates of a celestial body (the Moon, an Earth satellite, etc.) relative to a system of coordinates originating in the center of the Earth.

GEOCENTRIC DISTANCE. The distance of the Moon, an Earth satellite or any other celestial body from the center of the Earth.

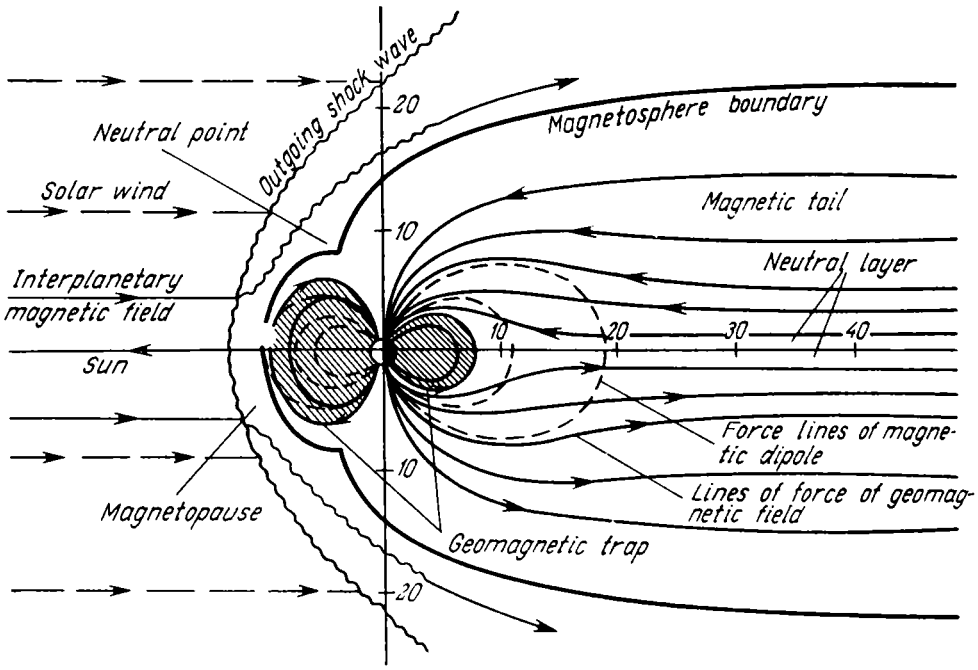
GEOCORONA. The outermost region of the Earth's atmosphere (by analogy with the outer region of the Sun's atmosphere—the solar corona). Consists mainly of charged particles possessing high temperature, but includes also a small quantity of neutral particles. The charged component consists of particles of the outer IONOSPHERE, "hot" photoelectrons filling the tubes of force of the MAGNETOSPHERE abating on the ionosphere lit up and ionized by the Sun, particles of the radiation belt trapped in the GEOMAGNETIC TRAP, and the particles in the tail part of the magnetosphere, whose motion is connected with the Earth's rotation about its axis. The neutral component is composed of particles of the EXOSPHERE, mostly hydrogen atoms, evaporating from the lower layers of the Earth's atmosphere.

GEODETIC SATELLITES. The satellites launched for determining precise coordinates of certain points on the surface of the Earth through accurate radio and optical measurement of the satellite's position from several points located on ground. The coordinates of some of these points are known, while the rest must be found. *Anna* and *Secor* launched by the USA are examples of geodetic satellites.

GEOMAGNETIC DISTURBANCE, index of. This index characterises the degree of disturbance of the geomagnetic field within a certain period of time. So far no unit of geomagnetic activity is agreed upon. Most simple are international characteristics: numerals 0, 1, 2 denoting the degree of disturbance during a day. In 1939 a practical 10-point (from 0 to 9) scale of 3-hour index K was introduced and is currently in use at the observatories

of the USSR. Each point corresponds to a definite amplitude of fluctuations of the field within a 3-h period with corrections for undisturbed diurnal movement (each observatory has its own scale of K index). Since 1951, average index K_p, referred to as planetary, has been introduced for evaluating the magnetic activity of the globe as a whole (is determined by averaging K indices for 11 specially selected observatories). The index has a 28-point scale (0_0, 0_+, 1_-, 1_0, 1_+, 2_-, 2_0, 2_+, etc.). Equivalent to the index K_p is the planetary amplitude a_p; the relationship between them is determined by a special table. More detailed than diurnal and 3-hour indices is the quarter-hour index Q. For investigating longer dependences (monthly, annual, secular) Bartels introduced the designation u, a measure of activity corresponding to interdiurnal variability.

GEOMAGNETIC TRAP. A region of the Earth's magnetosphere whose field has a structure that enables it to keep charged particles of near-terrestrial plasma within a limited volume. It is formed by magnetic lines of force



Meridional cross section of terrestrial magnetosphere (distances along coordinate axes are given in Earth radii).

closed within a relatively small volume and closely resembling in shape the lines of force of a dipole magnet; it begins at an altitude of several hundred km and extends to the limit of the magnetosphere on the sun-lit surface of the Earth in the equatorial plane. The principle permitting to hold charged particles in geomagnetic trap is connected with preservation of adiabatic invariants of particle motion in a magnetic field. Different regions of the

geomagnetic trap, filled by charged particles (corpuscular radiation) have come to be known as the RADIATION BELT OF EARTH.

The most widely known hypothesis of the origin of a part of corpuscular radiation in the geomagnetic trap is the neutron albedo hypothesis; also known is the theory of diffusion of outer charged particles in the geomagnetic trap due to disturbances of the 3rd adiabatic invariant (Φ) under the influence of sudden disturbances of magnetic field. Such diffusion should be accompanied by betatron-type acceleration of particles. According to another hypothesis, the particles are adiabatically sucked into the geomagnetic trap during magnetic storms. Whereas the diffusion hypothesis is based on the assumption of transition of charged particles from one invariant surface to another under the influence of field disturbances, the hypothesis of adiabatic suction explains the origin of trapped radiation by the deformation of the invariant surfaces themselves during magnetic storm. In the principal phase of a magnetic storm, the invariant surfaces corresponding to deep regions of the undisturbed geomagnetic field may come close to the upper limits of the geomagnetic trap, and during the restorative phase of the storm, return to their former place, capturing new charged particles and drawing them into the depth of geomagnetic trap. Adiabatic "sucking-in" should be accompanied mainly by betatron-type acceleration of particles.

GEOMAGNETISM. See TERRESTRIAL MAGNETISM.

GERMAN INTERPLANETARY TRAVEL SOCIETIES. (1) Founded in Breslau in 1927. The Society was headed by M. VALIER, H. OBERTH, I. *Winkler* and published *Die Rakete* (*The Rocket*) monthly magazine. The Society set up a rocket proving ground near Berlin in 1930 and began experimental work on liquid-propellant rockets. A liquid-propellant rocket designed by Winkler was successfully tested on March 14, 1931, and a liquid-propellant engine for the *Mirak* (*Minimum Rocket*), in May; towards the end of this year about 100 launchings of this rocket were practised. (2) Founded in Köln in 1937 as the Vereins für Raumschiffahrt (Space Flight Society). Began publishing the *Weltraum* (*Space*) magazine in 1940. (3) Founded in Stuttgart in 1948. In 1956 was named the Deutsche Gesellschaft für Raketentechnik und Raumfahrt (German Society for Rocket Engineering and Space Flight). (4) Founded in 1962. The aim of this Society is to give support to space research efforts promoted by the Ministry of Research Work of the German Federal Republic and to encourage scientific and technological progress in space research.

GERMAN ROCKET ENGINES. Intensive development of rocket engines was conducted in Germany before and during the World War II. A number of liquid-propellant engines for missiles and aircraft were created, as well as military solid-propellant missiles. Among the liquid-propellant engines was that of the *V-2* (*A-4*) rocket fired against London (thrust, 25 t; burning time, 60 s; weight, 1012 kg; power of the turbopump assembly, 680 hp; propellant, LOX and ETHYL ALCOHOL in 75% concentration), Walter's aviation liquid-propellant engine for the *Me-163* aircraft (thrust, 1,700 kg; weight, 188 kg; burning time, 4.5 min), etc. Development of military rockets in Germany was prohibited after the War. The German Federal Republic started recently to participate in the development of the

Europa-1 space launch vehicle (liquid-propellant rocket for the 3rd stage of the launch vehicle). This engine develops a thrust of 2.3 t, its burning time is more than 350 s, it fires NITROGEN TETROXIDE and AEROSENE-50.

GESHVEND, Fyodor (later half of 19th century). Russian engineer, one of the first to propose engineering designs for jet engines. His book *Obshcheye osnovaniye proyekta primeneniya reaktivnoy raboty para k zheleznodorozhnym parovozam* (*The General Principles of Project for Use of Reactive Power of Steam in Railway Locomotives*) was published in 1886. In 1887 he described a project of a jet plane and a multi-nozzle rocket engine in his book titled *Obshcheye osnovaniye ustroistva vozdukhoplavatelnogo parokhoda* (*The General Principles for Development of Aeronautical Steamer Ship*). He was the inventor of concentric nozzle adaptors which later became known as the Melot adaptors.

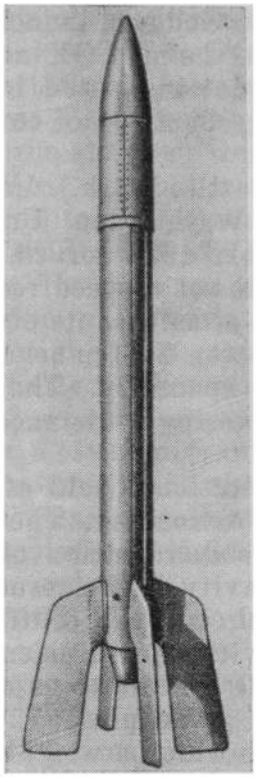
GIMBALS. A system of attaching an engine to the rocket vehicle, which makes it possible to change the position of the longitudinal axis of the rocket engine in respect of the axis of the space vehicle with the aim of changing the direction of the thrust vector in order to ensure flight control. Gimballing of liquid-propellant engines was developed at the GDL in 1931.

GIRD. See GROUP FOR STUDY OF REACTIVE MOTION.

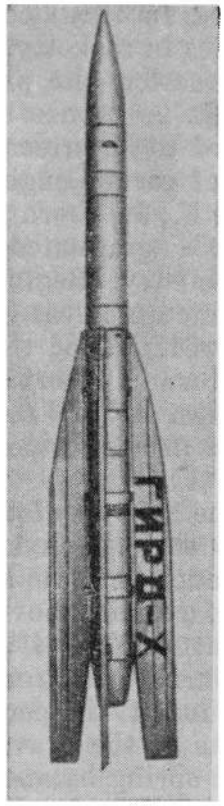
GIRD-09. First Soviet experimental liquid-propellant rocket developed in GIRD under the leadership of S. P. Korolev according to a design by M. K. Tikhonravov. Its take-off weight was 19 kg; propellant weight, 5 kg; and length 2.4 m. This rocket developed a thrust of 50 kg. It operated on LOX fed into the combustion chamber under the pressure of its own vapours, and solidified gasoline placed in the combustion chamber. The rocket was launched from vertical guides. The first rocket was launched on August 17, 1933, and rose to a height of about 400 m. In 1934, a small batch of *GIRD-09* rockets was built (designated by index 13). They were successfully launched to altitudes reaching 1500 m. The construction and launching of the *GIRD-09*, *GIRD-X* and other Soviet rockets marked the beginning of the practical development of liquid-propellant rocket engines in the USSR.

GIRD-X. One of the first Soviet experimental liquid-propellant rockets developed by GIRD under the leadership of S. P. Korolev. The design fundamentals were produced by F. A. Tsander. This rocket has a take-off weight of 29.5 kg and a length of 2.2 m, the propellant weighed 8.3 kg. The propellant (LOX and ethyl alcohol) was pressure-fed to the engine that developed a thrust of 65 kg. It was first launched on November 25, 1933. The rocket flew vertically to 75—80 m, then it departed abruptly from the vertical direction and fell at a distance of some 150 m from the launching pad. The engine operated for 12—13 s. The design of *GIRD-X* was the basis for the development of advanced rockets in 1935—37.

GLENN, John Herschel, Jr. (born 1921, Cambridge, Ohio). American astronaut, lieutenant-colonel of the USNavy. Upon graduation (1943) from the flight school of the Naval Air Training Centre, Tex., served with the USNavy. Graduated from the Navy Test Pilot Training School, Md., (1954), and Muskingum College (1961). In 1957 made a non-stop supersonic transcontinental flight. Joined the group of astronauts of the NASA 1959. Made the US first orbital flight in the *Mercury* (*MA-6*) spaceship on February 20, 1962, circling the Earth 3 times in 5 h.



GIRD-09



GIRD-X

GLIDING DESCENT. The re-entry of a spacecraft on a glide trajectory in the atmosphere of a planet, during which the spacecraft, in addition to being subject to the forces of atmospheric drag and gravity, also experiences aerodynamic lift due to the fact that it possesses an ANGLE OF ATTACK and LIFT/DRAG RATIO. The advantage of the gliding descent over the ballistic one is that the maximum g-loading is lower, and that some manoeuverability is provided.

g-LOAD. See WEIGHTLESSNESS.

GODDARD, Robert Hutchings (1882—1945). American scientist and one of the pioneers in rocketry. Graduated from the Worcester Polytechnical Institute in 1908. From 1914 was with Clark University (professor in 1919—43). In 1942—45 was Director of Research on Jet Propulsion for the Bureau of Aeronautics of the USNavy. Began experimenting with rockets in 1907. Between 1914 and 1940 was granted 83 patents for inventions in rocketry and after 1945 was considered the patentee of 131 more inventions derived from files. His book *A Method of Reaching Extreme*

Altitudes (published in 1919) contained the results of his theoretical and experimental studies in rocketry. In 1926 Goddard launched a liquid-propellant rocket in Worcester, the propellants being LOX and gasoline.

GODDARD MEDAL. A bronze desk medal instituted by the US Congress in 1959 as an award to be presented in recognition of contributions towards the advancement of rocket engineering.

GORDON, Richard F., Jr. (born 1929, Seattle, Wash.). US astronaut, USNavy officer. In 1951 graduated from Washington University where he specialized in chemistry. Beginning from 1953 served with the USNavy Flight Test and Meteorological Corps. He set a speed record on a transcontinental flight in 1961. Joined the group of astronauts of the NASA in 1963. Acting as co-pilot, made an orbital flight on September 12—14, 1966, together with C. CONRAD in the *Gemini-11* spaceship. The *Gemini-11* orbited the Earth 44 times in a 71-h period, covering a distance of about 1.9 million km.

GRAVIMETRY. The science of the gravitational field of the Earth and its application in geodesy, geophysics and astronomy. The gravitational field of the Earth is understood to mean the distribution of values of gravity on the Earth's surface and above it (gravity is the resultant of two forces: the gravitational attraction of the Earth and the centrifugal force caused by the Earth's diurnal rotation). Gravity measurements are made with (1) pendulum instrument, the periods of free oscillations of the pendulum of which are functions of the gravity at a given place; (2) gravimeter which is a high-precision spring balance and in which a weight is balanced by the force of a calibrated elastic deformed spring or a twisted elastic filament. All world gravimetric surveys are ultimately related to the Potsdam measurements (1906), where the absolute value of gravity is taken to be 981,274 mGal (1 mGal $= 10^{-3}$ cm/s^2). Recent absolute measurements of gravity at different localities revealed an error of 12.8 mGal in the Potsdam measurements, as a result, preparations are being made for transition to a new system.

Because of inhomogeneous density of the Earth's interior and irregular shape of the globe, the Earth has a complex gravitational field, which, for convenience, is regarded as being composed of two parts: the principal part, which is normal and varies regularly with geographic latitude, and an anomalous part, which is small in magnitude but complicated in distribution. The normal variation of gravity with altitude near the Earth is 0.03086 mGal/min. The anomalous gravitational field of the Earth is characterized by anomalies of gravity which are computed as the difference between the observed and the corresponding normal values of gravity; they reach hundreds of mGal. Investigations of the anomalous gravitational field are conducted to study the density inhomogeneities of the Earth's interior for purposes of geological prospecting. The attraction of the Moon and the Sun modify the gravity at the point of observation by magnitudes attaining 0.3 mGal. Judging by the magnitude of the differences between the luni-solar variation of gravity, the theoretical value calculated for an absolutely solid Earth, and the actually observed value, conclusions may be drawn concerning the elastic properties of the Earth. Measurements

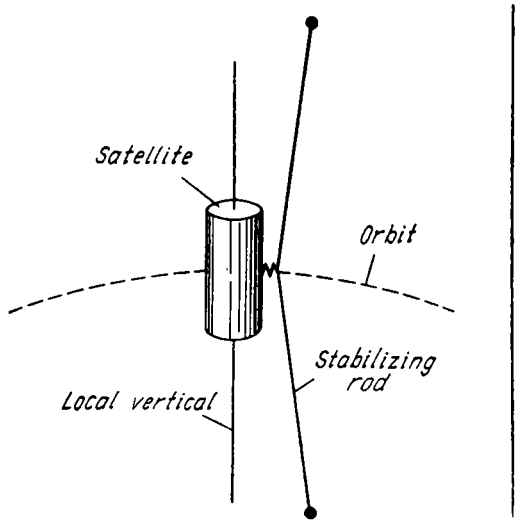
are also made to detect secular variations of gravity on the Earth. The knowledge of terrestrial gravitational field is necessary for computation of satellite orbits and rocket trajectories. On the other hand, the inhomogeneities of the gravitational field cause disturbances of the satellite orbits, and by studying these disturbances parameters are determined that describe the basic details of the shape of the globe and the outer gravitational field of the Earth. The most rational way is to investigate these parameters by combination of satellite, gravimetric, and geodetic observations.

GRAVITATIONAL FIELD OF EARTH. The field of force due to the Earth's attraction. Since the Earth is not a homogeneous sphere or a sphere with concentric distribution of density, its gravitational field has a complex structure. The potential of the gravitational field is ordinarily represented in the form of an infinite mathematical series, the first term of which stands for the attraction of a homogeneous sphere whose mass is equal to that of the Earth. The next most significant term of the series is the so-called 2nd zonal harmonic, due mainly to the compression of the Earth. This term is approximately 1000 times smaller than the first. The remaining terms of the potential of the gravitational field of the Earth are less than the first by a factor of 1 million and more.

GRAVITATIONAL MOMENT. The moment that acts upon a body located within a field of gravitation (of the Sun or a planet). Due to this moment, some satellites always expose only one side to the planets they accompany (e.g., the Moon and the Earth). The gravitational moment produces a negative effect and becomes a DISTURBING MOMENT at any change in the angular motion of the spacecraft. In certain cases, however, the gravitational moment can be used to advantage (see GRAVITATIONAL SYSTEM OF ORIENTATION).

GRAVITATIONAL POTENTIAL. A certain function of the coordinates of a point in space, describing the given gravitational field; its partial derivatives with respect to the coordinates are equal to projections, on the appropriate axes, of the gravitational force of the material body.

GRAVITATIONAL STABILIZER. See GRAVITATIONAL SYSTEM OF ORIENTATION.



GRAVITATIONAL SYSTEM OF ORIENTATION. A passive system of orientation based on the utilization of gravitational moment. The gravitational system of orientation of an Earth satellite orients one of the axes of the latter to the local terrestrial vertical; the other two axes may also be oriented in a suitable way, this corresponding to a triaxial orbital orientation of the satellite. The efficiency of gravitational orientation is improved by

elongating the satellite as much as possible along the vertically-oriented axis; in certain cases this is attained by the use of special outlying masses (weights) that are extended from the body of the satellite by means of telescopic or collapsible rods after the satellite has been placed into orbit. Two rigidly coupled outlying masses make up a so-called gravitational stabilizer (see Fig., p. 169); sometimes a flexible link is established between the Earth satellite and the stabilizer for damping the angular oscillations of the satellite and the stabilizer since a flexible connection is capable of absorbing the energy of these oscillations. Gravitational systems of orientation can be employed for satellites orbiting any planet having a sufficiently powerful field of gravitation. Such systems are less efficient in interplanetary flights due to the insufficient magnitude of the gravitational field of the Sun.

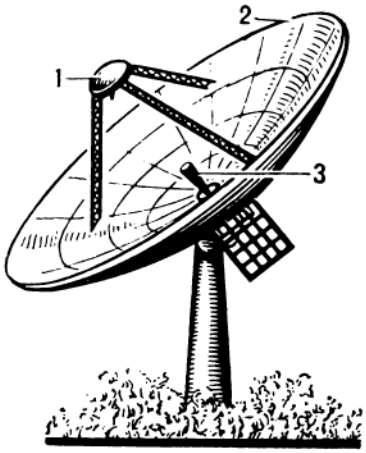
GRISSOM, Virgil Ivan (born 1926, Mitchell, Ind., died 1967, Cape Kennedy). American astronaut, colonel of the USAF. Served as an Air force pilot from 1944. In 1950 graduated from the Purdue University, Lafayette, Ind., as B. Sc. in mechanical engineering. Graduated from the Air Force Institute of Technology in 1955 and from the Air Force Experimental Flight Test School at Edwards Air Force Base in 1956. Joined the group of astronauts of the NASA in 1959. Made a suborbital flight of about 16-min duration on June 21, 1961, in accordance with the *Mercury* program. Was sent up into space together with J. YOUNG in the *Gemini-3* spaceship on March 23, 1965, orbiting the Earth 3 times in a 5-hour period. During this flight the astronauts performed the US first change of spaceship orbit. V. Grissom perished on January 27, 1967, when the capsule of the *Apollo* spaceship caught fire during ground tests.

GROUND NETWORK SIMULATOR. A set of equipment and instruments of the ground checkout and launching equipment used for checking the rocket-borne control system. The simulator equipment is usually truck-mounted or installed in the vehicle assembly building.

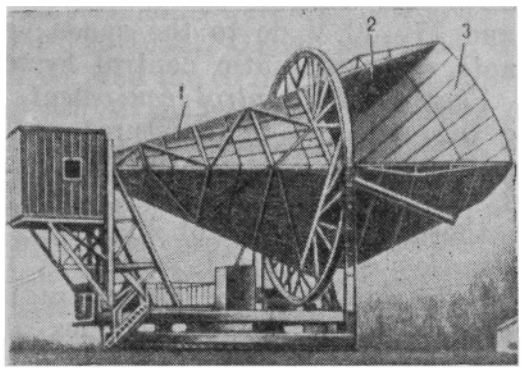
GROUND STATION of radio communication via Earth satellite. A set of equipment used for transmitting and receiving radio signals via COMMUNICATIONS SATELLITES. This communication is brought about by a directional transmitting and receiving antenna which is capable of radiating high power and receiving weak signals. The received signals of a satellite-borne transmitter are subsequently amplified by a highly sensitive receiver employing a maser or parametric amplifier. The information received by the ground station is relayed to subscribers along radio relay, cable and other types of communication lines.

GROUND STATION ANTENNA for radio communication via an Earth satellite. A directional antenna designed for the reception of weak radio signals emitted by an Earth satellite, spacecraft or automatic interplanetary station, and for the radiation of high-power radio signals. The following types of ground station antennas are in general use: Cassegrainian twin-reflector dish antennas and parabolic horn antennas. The twin-reflector dish antenna emits a narrow beam of radio waves, that is produced by a metal parabolic reflector having a spider-web or continuous reflecting surface up to 60 m in diameter, rotated mechanically for directing the maximum radiation towards the traveling point of the communication line. The para-

bolic horn antennas emit a narrow beam of radio waves in a similar manner and their aperture diameter equals 20 to 25 m. Ground station antennas operating in the microwave band provide a power gain of 60 dB, a side



Cassegrain two-mirror antenna.
1—hyperbolic mirror; *2*—parabolic mirror; *3*—exciter.



Horn-parabolic antenna.
1—horn exciter; *2*—horn aperture; *3*—parabolic mirror.

lobe attenuation of 40 dB, a DIRECTIVITY PATTERN width of 6 to 8′ and a NOISE TEMPERATURE of 10° to 20°K. The effective area of large antennas is as great as 2000 to 3000 m².

GROUND SUPPORT EQUIPMENT of space center. A complex of structures and systems of the launch complex and the maintenance area of a SPACE CENTER. From the viewpoint of the basic operations of rocket preparation and launching, the ground support equipment can be divided into the following groups. *Launch equipment* is designed for accepting and supporting the launch vehicle aligned for launch, for bringing to it fuelling, electrical, pneumatic, drainage, and other lines, and for the launching proper. *Transport-erecting equipment* is used for delivering the launch vehicle to the launch pad and erecting it. *Fuelling equipment* ensures filling the vehicle and spacecraft with propellants and compressed gases; it comprises fuelling units, pumping plants, compressor plants, receiver rooms, tanks, pipe fittings, pipe-lines and systems for remote and automatic control of propellant loading. *Transport equipment* is used for carrying the space vehicle components and propellants; it includes rocket-handling dollies, trailers and semi-trailers, crawler and wheeled transporters, railway cars, Diesel electric locomotives, motor barges, and the equipment of ships and aircraft adapting them for these kinds of cargoes. *Handling equipment* is used for hoisting and transferring operations during transportation, assembly, transfer and servicing of spacecraft. *Mating and assembly equipment* includes assembly jigs, mating units, mating and process trolleys, trestles, supports, crossarms, assembly fixtures and appliances, as well as equipment for welding the supergiant launch vehicle tanks. *Servicing equipment* ensures access of operators, delivery of instruments

and appliances to various levels of the space vehicles erected vertically on the launchers or in the vertical assembly building, and includes service towers and trusses, truck-mounted towers, lift trucks, service platforms, etc. *Alignment equipment* comprises optical instruments controlling the vertical and azimuth alignment of the launch vehicle. *Ground electric power supply equipment* ensures the supply of special currents and 27—30 V dc to the space vehicle, to ground instruments, and to remote and automatic control systems of the ground support equipment. *Thermostatic control equipment*, designed for ensuring and maintaining the required temperatures of the space vehicle components and of propellants, includes heating and refrigerating machines, refrigerating centers, air systems for thermostatic control of spacecraft, means for liquid thermostatic control of spacecraft, heat-insulating covers, etc. *Neutralization equipment* is aimed at neutralizing any spilled propellant as well as remaining toxic propellants and their vapours during fuelling, and components of launch vehicles after drainage of toxic propellants following an abortive launch. *Testing equipment* serves for testing instruments and components, subassemblies and stages of launch vehicles, as well as space vehicles fully integrated, the testing being performed both at the maintenance area and on the launch pad. The *launch complex data acquisition and handling system* watches physical values and processes in systems and structures of the ground support equipment during pre-launch and launch operations, it records the physical values and parameters of the processes that take place in erectors, launchers, fuelling equipment, determines the parameters of the gas-dynamical effect on the launcher components, estimates the behaviour of the structural elements, records the parameters of the acoustic field, etc. *Check-out-and-launch equipment* (the ground portion of the system controlling the launch and flight of the spacevehicle) ensures pre-launch preparation and sending the firing signals. Special fire-prevention equipment see under FIRE-FIGHTING SYSTEM OF LAUNCHING SITE.

GROUP FOR STUDY OF REACTIVE MOTION (GIRD). (1) Public organizations founded in 1931 under the Osoaviakhim (Society for Assisting Defence and Aviation and Chemical Construction) in Moscow (MosGIRD) and Leningrad (LenGIRD), and later on in Kharkov, Baku and elsewhere. (2) Research and development organization for the designing of rockets and engines, set up in Moscow in June, 1932, by decision of the Presidium of the Central Council of the Osoaviakhim. Along with the GAS DYNAMICS LABORATORY (GDL), GIRD played the principal part in the birth of Soviet rocketry. GIRD occupied premises in the basement at No. 19 Sadovo-Spasskaya street. S. P. KOROLEV, Chairman of the Scientific Technical Council of MosGIRD, was appointed chief of GIRD. The team of F. A. TSANDER, which until then had worked on a volunteer basis at the MosGIRD on the development of the liquid-propellant engine *OP-2* for the *РП-1* rocket plane, was put on the staff of GIRD. From August, 1932, GIRD was financed by the Red Army Board on Military Inventions after which three more design teams were formed; these were teams for the development of liquid-propellant ballistic missiles, for the development of ramjet engines and gas-

dynamic test beds, and for designing rocket planes and winged rockets. The teams were headed by M. K. Tikhonravov, Y. A. Pobedonostsev, and S. P. Korolev. A production team and a test station were set up as well. GIRD's initial task was to develop the simplest liquid-propellant rocket craft to gain the necessary experience. LOX was used as the oxidizer, with gasoline and ethyl alcohol as fuels. Experiments were carried out in burning metallic fuel in air. On August 17, 1933, GIRD launched the first Soviet liquid-propellant rocket *GIRD-09*, and the *GIRD-X* rocket on November 25, 1933. A number of other liquid-propellant ballistic and winged rockets were designed as well. A number of liquid-propellant engines (*OP-2*, *02*, *10*, etc.) as well as a hybrid rocket engine *09* were designed and tested. The flight tests of a model of a ramjet fired from a gun were successful; a supersonic wind tunnel was built and a system of propellant pump-feeding was tested. At the end of 1933 GIRD and GDL were merged into the world's first state owned Rocket Research Institute. From the GIRD came outstanding scientists and designers who took an active part in the development of Soviet rocket and space science and technology; theirs is an inestimable contribution to the development of rockets proper, artificial satellites, automatic interplanetary stations and spaceships. In recognition of GIRD's contribution to the development of Soviet rocketry, a 52-km long chain of craters on the far side of the Moon has been named after this organization. See also MOSCOW GROUP FOR STUDY OF REACTIVE MOTION and LENINGRAD GROUP FOR STUDY OF REACTIVE MOTION.

GUNPOWDER, BLACK (smoky). A heterogeneous solid propellant consisting of (% by weight): potassium nitrate (57—80), charcoal (13—20), and sulphur (8—22). Had been used in rocket technology until GUNPOWDER, SMOKELESS, was developed, to which it is inferior in performance and in the specific impulse obtained. Used in ignition devices. See also SOLID PROPELLANT.

GUNPOWDER ROCKET ENGINE. See SOLID-PROPELLANT ENGINE.

GUNPOWDER, SMOKELESS, for rockets. A homogeneous (double-base) solid rocket propellant, pyroxylin gunpowder in a non-volatile solvent, such as trinitrotoluene, nitroglycerine, and others. In the USSR development of a rocket burning this propellant was begun by N. I. Tikhomirov and V. A. Artemyev (GDL) in the 1920s. See also SOLID PROPELLANT.

GYROSCOPE (gyro). A rapidly spinning solid body so suspended from the guided object that its axis of rotation is able to change its angular attitude with respect to the base. The gyroscope can retain the direction preset to its spin axis and resist any changes of this direction caused by disturbing forces acting on the gyro. The gyro properties are inherent in rotating celestial bodies, artillery shells, turbine rotors, propellers, etc. Modern engineering employs the gyro as the main element of all kinds of gyroscopic devices and instruments widely used in automatic flight control systems of space vehicles and aircraft, and in other systems of gyrostabilization, for the purposes of navigation, measurement of rates of angular or translational motion, and for many other special purposes.

GYROSCOPE-STABILIZED PLATFORM. A platform whose angular position is kept fixed with respect to preset directions by the use of gyroscopes and

Gyroscopic stabilizers

a number of auxiliary devices (in particular, counteracting and follow-up electrical servomechanisms). Gyroscope-stabilized platforms utilize the ability of a gyroscope to retain its initial angular position with a considerable margin of stability in respect to disturbances tending to change this position. Gyroscope-stabilized platforms are used in spacecraft systems of space navigation.

GYROSCOPIC INTEGRATOR. One of the most widely used types of LINEAR ACCELERATION INTEGRATORS. The gyroscopic integrator converts the force of inertia, that arises at acceleration of the spacecraft, into a torque applied to the gyro that rotates at a strictly calibrated speed; the angle of deflection (precession) of the gyro accumulated due to the action of this torque serves as a measure of the APPARENT VELOCITY of the spacecraft.

GYROSCOPIC STABILIZERS. The actuators of the system of orientation of a spacecraft employing gyroscopes having one (see REACTIVE GYRATING MASSES), two or three angular degrees of freedom with respect to the body of the spacecraft. The control torques applied to the spacecraft are due either to changes in the rate of gyro rotation or to a forced precession of the axes of rotation within the gyro housing. Combined use of these methods is also practised.

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HAMMAGUIR. A former French rocket test range on the territory of Algeria. The Hammaguir range was used for testing combat missiles, launching Earth satellites by means of *Diamant* launch vehicles, and for testing the rocket stages developed under the programme of the European Launcher Development Organization. Two overland rocket firing ranges were used for this purpose: one stretched southwestward for some 1000 km in the direction of the town of Tindouf, and the other in the southeastern direction for some 3000 km towards Lake Chad. After the evacuation of this range from Algeria in 1967, the creation of space research centres was begun in the territory of France proper, as well as in French overseas possessions such as in French Guiana (see FRENCH GUIANA RANGE) and on the islands in the Pacific Ocean. A rocket range is under construction on the shore of the Bay of Biscay near the town of Biscarrosse. From this site rockets are to be fired in the direction of French Guiana. Observations of the rocket flight will be performed from a tracking station which has been built on the Azores. A number of ships and aircraft have also been equipped for the purposes of tracking. Several launch complexes have already been erected at the Biscarrosse range, these facilities being employed for experimental launches of combat missiles (including launches from silos) and of individual stages of launch vehicles. Launch complexes for civil application are under construction.

HEAT EXCHANGER. A device designed to transfer heat from one heat carrier to another. By the principle of operation, heat exchangers may be either the surface or mixing type. In the former, the heat carriers are separated by a partition, and heat is transferred to the surface of a solid body, by convection or radiation. In the mixing type devices, the heat exchange is due to direct contact and mixing of hot and cold heat carriers.

HEATING CAPACITY of rocket propellant. The amount of heat evolved in decomposition or complete combustion of 1 kg of the propellant at a given EXCESS-OF-OXIDIZING-ELEMENTS COEFFICIENT. It is determined at a constant pressure, provided the temperature of the initial and final substances is the same (20°C or 25°C). Its value depends on the excess-of-oxidizing-elements coefficient and attains a maximum when this coefficient is equal to 1. Usually a lower heating capacity is employed which does not take into account the heat of condensation of water vapours in the combustion products. It is characterized by the maximum amount of heat evolved during decomposition or combustion of the propellant. The full heating capacity of a propellant is not achieved in the combustion chamber of rocket engines due to imperfections of injectors. Besides, the high temperature of the combustion products results in the DISSOCIATION of the components. The basic characteristic of a rocket propellant, the SPECIFIC IMPULSE it produces, depends considerably on the heating capacity, but the latter alone does not determine it, because the efficiency of the combustion products depends likewise on their composition. When the coefficient of excess of oxidizing elements equals 1, the heating capacity is approximately equal to: 1000—2500 kcal/kg for solid propellants; 1500—3000 kcal/kg for liquid propellants (the greater value is for propellants based on fluorine); when metals burn in oxygen or fluorine, it can attain a value of 5000—5700 kcal/kg, e.g., for oxygen + beryllium, 5720, for fluorine + lithium, 5650 kcal/kg.

HEATING RATE. The flow of heat per unit of time related to unit of surface. It characterizes the heat load of the heated surface. The transfer of heat from the hot combustion products (working fluid) to the walls of the thrust chamber is caused by the convective and radiative heat exchange. The convective heat exchange is caused by turbulent motion of particles of the combustion products, while radiation heat exchange, by their radiation. Because of the high stagnation temperatures and considerable mass flow rate of the working fluid, the values of heating rate are very high, reaching in the throat section of nozzle of a liquid-propellant rocket $(50—70)\cdot10^6$ kcal/m$^2\cdot$h, the heating rate due to convection being 7—15 times greater than that of radiation. The maximum permissible (critical) heating rates are limited by the critical temperatures of the walls on the side of the hot gases or on the side of the coolant. The heating of walls above the critical level on the side of the hot gas leads to burn-throughs of the wall, on the side of the coolant, to frequent instances of an intolerable thermal decomposition of the coolant. Thermal decomposition of some coolants (e.g., unsymmetrical DIMETHYL HYDRAZINE, HYDRAZINE, HYDROGEN PEROXIDE, etc.) causes evolution of heat facilitating destruction of the walls; in this case the decomposition may be followed by an explosion. The thermal decomposition of a number of coolants (e.g., hydrocarbons, unsymmetrical dimethyl hydrazine, PENTABORAN, etc.) leads to the forming of solid sediments on the coolant side of the wall which, because of their low heat conductivity, hinder cooling and cause destruction of the walls.

HEAT RELEASE RATE OF ENGINE. The amount of heat released in a unit of volume of the combustion chamber per unit of time. In heat release rate, rocket engines exceed all other thermal engines. This value for a liquid-propellant rocket engine is 8,000,000 kcal/m$^3\cdot$s, which is several hundred times greater than in a jet engine, and tens of thousands of times greater than in best boilers.

HELIOCENTRIC COORDINATES. Coordinates of a celestial body relative to the system of coordinates with the origin in the centre of the Sun. Heliocentric coordinates are often used in describing the motions of major planets, asteroids, comets, and other celestial bodies.

HELIOCENTRIC DISTANCE. The distance of a celestial body (planet, comet, etc.) from the centre of the Sun.

HELIUM, He. An inert gas. Boiling point—268.9° C. It is used to pressurize tanks with cryogenic propellant components. The substitution of helium for nitrogen is considered expedient from physiological and technological points of view, since this would reduce the danger of DECOMPRESSION SICKNESS, lower the weight of the spaceship and the amount of energy consumed by forced ventilation. A helium-oxygen environment at comfort temperatures does not produce any unfavourable effects on human organism.

HELIUM LEAK DETECTOR. A highly sensitive instrument used for detecting leakage of helium from a spacecraft or individual stages of a launch vehicle during vacuum tests by means of pure or diluted helium. The detector consists of a mass spectrometer, a mass-spectrometer chamber and a secondary indicator.

HETEROGENEOUS SOLID PROPELLANT. A mechanical mixture of finely ground solid oxidizer with liquid fuel that hardens on polymerization. Oxygen-rich inorganic salts are used as the oxidizer, such as ammonium, lithium, sodium and potassium nitrates or perchlorates. Sometimes use is made of organic salts, such as ammonium picrate. The most extensively used oxidizers are: potassium perchlorate $KClO_4$, ammonium perchlorate NH_4ClO_4, and ammonium nitrate NH_4NO_3. Composite propellants containing potassium perchlorate have a rather low SPECIFIC IMPULSE, but high density. Ammonium perchlorate, at present the basically used oxidizer in composite propellants with a high specific impulse, shows low values of the exponent in the equation for the dependence of burning rate on pressure. Ammonium nitrate is cheap, easily available, and widely used, but the propellants on its basis have a rather low specific impulse, slow burning rate, are hygroscopic and physically unstable due to its tendency to polymorphic transformation. Lithium perchlorate has good energetical characteristics, but it is hygroscopic and costly.

Use is made of asphalts, bitumens, and synthetic polymers, such as thiokols, polyesters, urethans, synthetic rubber (polybutadiene, including carboxyl and nitrile rubbers, etc.), polyethylene, polypropylene, synthetic resins (phenolic epoxy, styrene, acrylic, polyamide, etc.) as fuels which are, in addition, binders.

The physical and mechanical properties of composite propellants, namely, elasticity, tensile strength, elongation, second-order transition temperature, etc., are determined chiefly by properties of the binding material. With the aim of improving the producibility, physical, mechanical, and energetical characteristics of the propellants, use is made of plasticizing additives (nitrocompounds, nitrates, acetylene and other compounds). Metals (aluminium, magnesium, beryllium), usually in the form of fine powders, are added in order to increase the specific impulse; attempts are being made to introduce metal-containing compounds. Composite propellants may be cast in special cases or directly in the combustion chamber (with subsequent polymerization), or be processed by extrusion.

Composite propellants have a specific impulse of 170—240 s and, if metals are added, up to 250—265 s at a gas expansion ratio of 40. They are more extensively used than HOMOGENEOUS SOLID PROPELLANTS.

HETEROSPHERE. The region of the atmosphere above the homosphere; the heterosphere is characterized by variation in composition and structure of the atmosphere with height. In the lower part of the heterosphere (at altitudes of ~80—150 km) the composition changes mainly due to an increase in gas dissociation as the height increases, as well as the diffusion separation of atmospheric components. In the upper part of the heterosphere (above ~150 km) the distribution of partial concentrations of the neutral atmospheric components is mutually independent and can be described by the hydrostatic equilibrium equation considering the temperature variation with height. Still higher, in the EXOSPHERE, the distribution of particles of different mass is governed by more complex laws.

HETEROTROPHIC ORGANISMS. Living organisms that feed mainly on ready-made organic substances. This distinguishes them from autotrophic

organisms] (see AUTOTROPHS), which feed on inorganic materials only. Heterotrophic organisms include all animals and a greater part of the microorganisms (except photo- and chemi-synthesizing bacteria). Beside organic substances, heterotrophic organisms can utilize mineral salts and gases. The heterotrophic link in a LSS should provide the spaceman with sufficient amounts of nutritionally adequate animal protein and fat (see FOOD RECYCLING). The simplicity of yeasts makes them reliable and economically advantageous heterotrophic organisms, but they contain considerable quantities of purine and pyrimidine bases which are toxic for man. The spaceman's rations may be replenished with certain aquatic invertebrates grown separately from or together with fish, as well as the fish proper. Only a few species of fishes, however, such as carp, white Amur fish, etc., can live, reproduce well and have a sufficiently high rate of growth in the specific environment of a sealed cabin (limited volume of water, deficiency of oxygen, absence of diversified food, etc.).

Fish and fowl (hens), as well as certain species of aquatic invertebrates, in turn, need a definite amount of nutritionally adequate animal proteins. Consequently, the link must include so-called primary utilizers of organic substances, e.g., lower heterotrophic organisms. Promising are heterotrophic organisms that constitute ACTIVE SLUDGE.

HIGH-ALTITUDE TRAINING. A complex of measures taken to increase the organism's resistance to hypoxia. The extremum effects of space flight factors often cause hypoxic states. The emotional stress is accompanied by a sharp increase in respiration and heart rates which, in turn, may cause (as a result of hyperventilation) carbon dioxide deficiency, blood sugar fall and insufficient utilization of oxygen by tissues (primarily, cerebral). High-altitude training is usually undergone in PRESSURE CHAMBERS. It is however, more effective in highland conditions. A definite stage-by-stage training program is followed and, combined with rational nourishment, it promotes stable adaptation of the organism to the combined action of various environmental factors.

HIGH-BOILING PROPELLANT COMPONENT. The component of a liquid propellant (oxidizer or fuel), with a b.p. $\geqslant 25°C$ under operating conditions (see also LOW-BOILING PROPELLANT COMPONENT).

HIGH-FREQUENCY VIBRATION of rocket engine. See SELF-EXCITED VIBRATION.

HOHMANN, Walter (born 1880). German scientist, mathematician and mechanical engineer. Graduated from the Institute of Technology, Munich in 1904. Was engaged in theoretical studies of interplanetary flight since 1914. His work *Die Erreichbarkeit der Himmelskörper* (*The Accessibility of Celestial Bodies*) was published in 1925. The ellipse, linking the orbits of two planets and used as the flight path for travel between these planets with minimum propellant consumption, is sometimes referred to as the Hohmann ellipse.

HOMEOSTASIS. Dynamic preservation of relative stability of physiological constants such as body temperature (isothermia), blood pH (isoponia), metabolic processes, blood sugar level, arterial pressure (isotonia) and other vital physiological functions of the organism. The motion "homeostasis"

is widely applied in studying physiological regulation mechanisms. On the basis of homeostasis principles, AVIATION MEDICINE and SPACE MEDICINE are searching for ways and means of creating the artificial environment required for a prolonged space flight of man.

HOMOGENEOUS SOLID PROPELLANT. A propellant composed of chemical compounds containing combustible and oxidizing elements. This is a solid solution of these components. Such propellants are based on cellulose nitrate $C_6H_7(OH)_{3-x}(ONO_2)_x$ with varying contents of the ONO_2 radical. Even on complete substitution ($x = 3$), the oxygen balance of cellulose nitrate is negative. In homogeneous propellants cellulose nitrate is dissolved in involatile solvents, such as nitroglycerine $C_3H_5(ONO_2)_3$, diethylene glycole dinitrate, and others, with the addition of stabilizers, plasticizers, catalysts to increase the rate of burning, and other additives. Propellants based on cellulose nitrate with a low nitrogen content and an involatile solvent, reprocessed at elevated temperatures (80—90°C) without the addition of a volatile solvent, are called ballistites. Propellants to which volatile solvents are added in the process of their preparation, but are removed after mixing the components, are called cordites. The use of volatile solvent in preparation of cordites permits the utilization of cellulose nitrate with a high nitrogen content, which makes cordite ammunition energetically more advantageous than ballistites. Sometimes the properties of the propellants are improved by the addition of inorganic oxidizers, metallic powders (aluminium, magnesium, etc.). The fabrication of charges for homogeneous solid propellants is carried out by the usual method applied in the processing of thermoplastics.

Homogeneous solid propellants have a specific impulse of 180—230 s at a gas expansion ratio of 40; the exponent in the equation for the dependence of burning rate on pressure is 0.4—0.75. At the present time HETEROGENEOUS SOLID PROPELLANTS are more widely used than homogeneous propellants.

HOMOSPHERE. The region of the atmosphere from the Earth's surface approximately to the MESOPAUSE (80—90 km) including the TROPOSPHERE, stratosphere and MESOSPHERE; in this region there is practically no change in air composition and the mean molecular weight of the air is constant.

HORIZON, true. The great circle of the CELESTIAL SPHERE in the plane perpendicular to the vertical line at the point of observation. The true, or mathematical, horizon should be distinguished from the apparent, or physical, horizon, i.e., the line where earth and sky appear to meet and the projection of this line upon the celestial sphere.

HORIZON SCANNER. See VERTICAL-LINE PLOTTER.

HOSES. Flexible pipelines used for supply of air or water. Air hoses are made of rubberized cloth and have stiffening rings for retaining the shape of the hose. These hoses are used, as a rule, for supplying hot air to heated areas, such as the engine compartment, instrument compartment, nose part, etc. Plenum and suction water hoses are to be distinguished; suction hoses are made of two layers of rubber or rubberized cloth (that is subsequently vulcanized) between which a helical wire is provided for resisting the external pressure; plenum hoses are made of flax, tow or cotton cloth. Hoses are interconnected by means of quick-release couplings.

HOUR ANGLE. Coordinate of the equatorial system of celestial coordinates. The angle between the celestial meridian of an observer and the declination circle of a celestial object measured westward from the meridian from 0° to 360° or from 0 h to 24 h.

Hour angle

HUMAN ENGINEERING (engineering psychology). A branch of psychology that studies man's psycho-physiological abilities in his intercourse with the machine and the laws governing the functioning of the man — machine system. Human engineering is highly important for the development of space flight. Its purpose in this sphere is to provide scientifically valid requirements that psychology and physiology promote for spaceship equipment and its arrangement, indication and display systems, and for the selection of means of manual and semi-automatic control of spaceships (including approach and docking), etc.

HUMIDITY of air. The content of water vapour in the air, e.g., in the atmosphere of a sealed cabin. Air humidity combined with air temperature affects the human organism and performance of the equipment of the spaceship. Air humidity can be measured as partial pressure of water vapour, absolute humidity (amount of water vapour in g per m^3 of air), relative humidity (ratio of absolute humidity to the maximum humidity possible at the given temperature), dew point, etc. Humidity can be increased by some of the links in the LSS (BIOLOGICAL AIR REGENERATION, biological links, etc.). Water is formed when lithium hydroxide is used to eliminate the carbon dioxide; water vapours enter the cabin atmosphere together with oxygen when electrolytic dissociation of water is effected. A relative humidity of 30—70% at an ambient temperature of $+20 \pm 10$°C should be maintained in spaceship cabins.

HYBRID ROCKET ENGINE. A rocket engine firing a propellant composed of solid and liquid components. The solid component is usually placed in the combustion chamber whereto the liquid component is fed. As a rule, it is the fuel that is in the solid state. The hybrid rocket engines are in the stage of development. A hybrid rocket engine was first designed in the GIRD in 1933 (ENGINE 09).

HYDRAULIC CIRCUIT of temperature control. The system which ensures heat transfer from space vehicle inner volumes, individual structural elements, and equipment, to a radiating surface. The hydraulic circuit includes a conduit with a liquid heat carrier circulating in it, pumps and fittings to maintain and control this circulation, and gas-liquid heat exchangers to transfer the heat from the gas in the airtight vehicle compartments to the heat carrier.

HYDRAULIC DRIVE. A power unit used for actuating the systems of liquid-propellant engines, spacecraft, the lifting and turning mechanisms of launchers, as well as hoisting and swivelling parts of launchers, lifting erector arms and gantries at space centres. The actuators of the hydraulic drive are hydraulic motors and cylinders (HYDRAULIC JACKS).

HYDRAULIC JACK. A hydraulic actuator of erectors, launchers, servicing and hoisting equipment, etc., of a space centre. Used for hoisting and vertical alignment of rockets on launchers, lifting the erector arms and gantries, transferring service towers from transport carriages onto the supports

of the launch pad, etc. The operating fluid pressure in a hydraulic jack reaches 200 kg/cm^2, the cylinder diameter is 2000 mm, the piston working stroke (for single-stage jacks) is up to 10,000 mm. The working stroke can be increased by the use of telescopic hydraulic jacks.

HYDRAULIC NON-RETURN VALVE. An element of the hydraulic systems of erectors, launchers or other units of the ground support equipment, permitting the fluid flow in a pipeline in one direction only. Non-return valves installed on pipelines directly at the hydraulic jacks that lift the erector arm or gantry, lock the fluid in case of rupture of the hydraulic pipeline, thus preventing a spontaneous drop of the arm.

HYDRAULIC SHOCK ABSORBER. A hydraulic device for supporting the umbilical towers and cable masts, umbilical lines, collapsible launcher supports, etc., when these are thrown off from the launch vehicle at the blast-off. The shock absorber damps down the impacts of the falling elements against the supports and reduces the maximum forces acting on these elements, thus allowing their re-use. The absorber comprises a hydraulic cylinder, piston, spring and orifice regulator for adjusting the area of the aperture through which the hydraulic fluid can pass.

HYDRAULIC SUSPENSION OF LAUNCHER. A combination of the hydromechanical supports, the hydraulic system and the elements controlling the launcher supports, designed for accepting a launch vehicle from the erector when the end of the launch vehicle vibrates with respect to the supports, vertical alignment of the launch vehicle and lowering it onto the previously aligned supporting surface of the launcher. The hydraulic suspension prevents heavy impacts when the hydromechanical supports are brought into contact with the end of the launch vehicle and it rules out interface overstresses at the final moment of lowering the launch vehicle on the supporting surface. The hydraulic suspension excludes peak loads on the launch vehicle structure during erection and ensures a higher uniformity of the forces acting on this structure.

HYDRAULIC VALVE UNIT. A group of hydraulic valves installed on one support or frame and designed for centralized control of a system or a unit in the ground support equipment, or of a complex of operations performed by this system or unit.

HYDRAZINE, N_2H_4. A high-boiling liquid fuel and monopropellant for liquid-propellant engines. It is colourless, hygroscopic, fumes in the air, absorbs oxygen and carbon dioxide from atmosphere. Its density is 1.008 g/cm^3 at 20°C, m.p., 1.5°C, b.p., 113.5°C. Poisonous, soluble in water, alcohols, ammonia, and other solvents. Stable at room temperature and does not decompose without access of air. When submitted to catalytic or thermal decomposition, it generates a hot gaseous mixture consisting of hydrogen, nitrogen, and ammonia. Hydrazine is liable to explode on decomposition if overheated in a closed chamber and under the effect of powerful impulses. It only slightly corrodes many metals, but in the presence of oxygen attacks copper and its alloys, the copper ions catalyzing the decomposition. When used with NITROGEN TETROXIDE its effectiveness is a little higher than that of unsymmetrical DIMETHYL HYDRAZINE at a low gas expansion ratio in the nozzle, while at a high gas expan-

sion ratio it is somewhat inferior to the latter. It is widely used as a fuel component (see AEROSENE-50) with nitrogen tetroxide, forming self-igniting propellants, and also as a monopropellant for auxiliary rocket engines. The combination of hydrazine and water (hydrazine hydrate) was used in Germany in the 1940s.

HYDROCARBON FUELS. Fuels for liquid-propellant engines. Hydrocarbon compounds and their mixtures, mainly of petroleum origin, e.g., KEROSENE and products produced by reprocessing kerosene, TURPENTINE, and synthetic hydrocarbons. Fuels obtained from petroleum are cheap, their supply is not limited and they are extensively used in rocket technology in combination with various oxidizers. Certain synthetic hydrocarbon fuels ensure a higher specific impulse and have a greater density than that of fuels derived from petroleum, however, they are costly and in limited supply. Hydrocarbon fuels were proposed for use in liquid-propellant rockets by K. E. Tsiolkovsky in 1911.

HYDROGEN, liquid, H_2. A cryogenic fuel for liquid-propellant engines. A transparent colourless liquid, the lowest-boiling (except helium) and lightest of all liquids; density, 0.071 g/cm^3 at —253°C; m.p., —259.2°C; b. p., —252.8°C. Not poisonous, inflammable; mixtures of hydrogen and air are explosive. Noncorrosive; structural materials in contact with liquid hydrogen should retain the required mechanical properties. Notwithstanding its low density, it is the most effective fuel for the upper stages of the rocket. Used in combination with LOX; its use with liquid fluorine is at present under test. Liquid hydrogen is the most effective working fluid for nuclear rocket engines now under development. Its low b.p. makes its handling difficult, especially as concerns long-term storage. Hydrogen is obtained by electrolysis of water or by intensive cooling of gas mixtures containing free hydrogen. Proposed for liquid-propellant engines by K. E. Tsiolkovsky in 1903.

HYDROGEN PEROXIDE, H_2O_2. A high-boiling single-component LIQUID PROPELLANT and OXIDIZER. The source for steam-gas generation for driving turbo-pumps of liquid-propellant engines, etc. Used in the form of aqueous solutions of high concentration (up to 99%). A colourless, odourless liquid; b.p., 152.6°C; m.p., —0.89°C; density, 1.46 g/cm^3. It is poisonous, presents explosive hazards and burns the skin. Hydrogen peroxide and its solutions are not sufficiently stable. Decomposition is accelerated in the presence of small amount of catalytic impurities. Copper, silver, iron corrosion products and other substances are decomposition catalysts. Stabilizers are added to increase its stability. Some fuels ignite spontaneously with hydrogen peroxide. Under the effect of elevated temperatures or catalysts hydrogen peroxide decomposes to oxygen and water (steam-gas) with the evolution of heat; the temperature of the steam-gas depends on the concentration of hydrogen peroxide: 560°C for a concentration of 80%, 1000°C for a concentration of 99%. Used as an oxidizer with kerosene; in the future may be used with PENTABORANE and BERYLLIUM HYDRIDE. Proposed for use in liquid-propellant engines in 1930 (GDL).

HYDROGEN PEROXIDE HEATER AND SERVICER. A portable unit of the ground support equipment for transporting high-concentration hydro-

gen peroxide, heating it to, or maintaining it at the required temperature, and delivering it into the space vehicle tank. It comprises a hydrogen peroxide tank immersed in a water bath, furnace, pumping plant, plenum and suction pipes with pipe fittings, and system of telethermometers with indicators showing the temperature of hydrogen peroxide in the tank and that of water in the heating system. The hydrogen peroxide tank has a metering unit for dispensing preset quantities of hydrogen peroxide into the space vehicle tank.

HYDROLYSIS OF UREA. A chemical reaction of double decomposition between urea (carbamide) and water. It can be accomplished by physicochemical or microbiological methods. Both techniques may be used in LSS to obtain aqueous ammonia or nitric acid from urea.

HYDROMECHANICAL JACK. A hydraulic jack provided with a mechanical device for accurate setting of the working stroke length and locking the jack in this position. Hydromechanical jacks are used in launchers (as hydromechanical supports), erectors, transport vehicles, mating machines, etc. One type of hydromechanical jacks is a lead-screw-and-nut pair whose screw is rigidly secured in one of the hydraulic cylinders while the sliding nut is axially immobilized by another hydraulic cylinder. There is also an electrically-controlled friction brake for locking the sliding nut and, consequently, the entire hydromechanical jack.

HYDROPHILIC MATERIALS. Substances with high adsorptive affinity to water which spontaneously form colloid solutions in water or other liquids. These are materials prepared on the base of cellulose, certain woven and non-woven textiles, minerals with ionic crystal lattices (carbonates, silicates, oxides and hydroxides), some metals, etc. Hydrophilic materials are used in the LSS and other systems of spaceship to separate phases in conditions of weightlessness, to direct the flow of liquids (materials for capillary pumps and the so-called wick materials), to obtain definite orientation of liquids in vessels, etc.

HYDROPHOBIC MATERIALS. Water-repelling substances, such as paraffin, fats, waxes, fluoroplast, etc. They are used in the LSS and other systems of spaceship to separate gas-and-liquid mixtures in weightless conditions, to direct the flow of liquids, etc.

HYDROPONICS. Soilless growing of plants in water solutions of mineral salts or of artificial substrates. The most important methods for nutriculture in space are the method of gravel cultures and the aeroponics. The method of gravel cultures provides for growing of the plants on a substrate, the nutrient solution being either periodically fed from underneath and drained into a reservoir, or sprinkled from above. A light-weight substrate for the gravel culture method or its complete absence in aeroponics gives a substantial weight reduction of the space greenhouse.

HYPERBOLA. A 2nd-order curve, the locus of points the difference of whose distances from two fixed points (loci) is constant.

HYPERBOLIC MOTION. The motion of a celestial body along a hyperbola. Certain motions in the PROBLEM OF TWO BODIES are examples of hyperbolic motion. Some comets and spacecraft, flying towards the Moon and planets, move in orbits closely resembling hyperbolas. In studying the

trajectories of such bodies their motions can be considered hyperbolic, as a first approximation.

Hyperbolic velocity

HYPERBOLIC VELOCITY. The velocity exceeding the PARABOLIC VELOCITY. If the initial velocity of a body is hyperbolic, the UNDISTURBED motion will be hyperbolic (see HYPERBOLIC MOTION).

HYPERSONIC RAMJET ENGINE. A ramjet engine intended for operation at hypersonic flight speeds, i.e. at MACH NUMBERS >5 or 6. It is characterized by the combustion of fuel in a hypersonic flow. This engine can be used on AEROSPACE PLANES.

HYPOKINESIA (hypodynamic, relative adynamia). Diminished muscular mobility. During space flight, hypokinesia may be due to the confinement of the spaceman to a small cabin and to WEIGHTLESSNESS.

HYPOKINESIC SICKNESS. A complex of persistent functional disturbances due to limited muscular activity. The main symptoms are: tendency towards bradycardia and bradypnea, vascular and muscular hypotonicity, disturbance of balance, general weakness, deterioration of the appetite, disturbances of circulatory regulation shown by orthostatic test, increased hemoconcentration, decalcification, etc. (see HYPOTENSION). The main prophylaxis in space flight conditions is artificial gravitation and dosed muscular effort.

HYPOTENSION, orthostatic (orthostatic hypotonia). A fall of the systolic and diastolic pressure below 105 and 60 mm Hg, respectively, due to the change from prone or sedentary to upright position. It is often accompanied by tachycardia.

HYPOXIA. Low oxygen content. The hypoxic or respiratory form of oxygen deficiency is due to deterioration in arterialization (oxygen saturation) of the venous blood in the lungs. It may occur when there is a reduction of the partial pressure of oxygen in the air inhaled, or hyperventilation under the effect of accelerations or other factors. Hemic hypoxia or the hemic form of oxygen deficiency develops when there is a drop in the quantity of oxygen transferred by the blood and is due to the reduced oxygen capacity of the blood. This may be caused by hemopoietic disorders due to radiation, blood loss, formation of carboxyhemoglobin (combination of hemoglobin and carbon monoxide) or methemoglobin (combination of hemoglobin with oxidants). Circulatory hypoxia may occur in space flight for a short time during the change from acceleration condition to weightlessness, and, especially, during re-entry. Tissue hypoxia is a form of oxygen deficiency caused by inhibition or complete inactivation of respiratory enzymes (redox group, i.e., dehydrases or oxidases), due to which the tissues cannot assimilate the oxygen from the blood that irrigates them. This form may occur because of disturbances of vitamin metabolism (since some vitamins are elements of the enzyme structure) or because of intoxication by certain poisons, e.g., cyanides.

IGNITER. A device used for IGNITION in a rocket engine.

IGNITER PROPELLANT. A liquid propellant fed into the rocket engine at starting-up for chemical ignition of the main propellant. First applied by the GDL in *OPM-50* and *OPM-52* (1933).

IGNITION. The process of initiation of combustion of the propellant. In rocket engines use is made of CHEMICAL IGNITION, PYROTECHNICAL IGNITION and ELECTRIC IGNITION.

IGNITION DELAY OF PROPELLANT (induction period). The interval of time between the beginning of ignition of a propellant (or initial contact of hypergolic components of a propellant) and initiation of combustion, characterized by a rise in temperature in the reaction zone accompanied by the appearance of a flame. During this period the preliminary physical processes (heat transfer, evaporation of the components, etc.) take place, as well as chemical pre-ignition reactions with a low thermal effect. The ignition delay period should be short enough to assure safe start-up and, in some cases, stable burning. It depends on the type of propellant and the conditions of ignition. An ignition delay of a few hundredths of a second is tolerable.

IMPULSE TURBINE. A turbine in which the working fluid's potential energy is transformed into kinetic energy only in the stator nozzle. High-speed impulse turbines are usually employed in the turbopump units of rocket engines.

INCLINATION. See ORBITAL ELEMENTS.

INDUCTION at firing. The process of mixing the rocket jet efflux with atmospheric air inside the gas ducts of hard or semihard silo launchers, so that the jet efflux acts as the inducing flow to suck the atmospheric air into the gas ducts, the air being the induced flow. The build-up of the induction indicates that the cross-section areas of the gas ducts have been chosen correctly, and no back-flow of gas appears.

INDUSTRIAL RADIO INTERFERENCE. Disturbances caused by electrical installations, devices, instruments and networks whose operation is accompanied by sparking or arcing (electric welding sets, engine electric ignition systems, etc.). This type of interference is manifested mainly within broadcast bands, but is also liable to interfere with the reception of weak radio signals received from spacecraft and satellites on the the HF and VHF bands. The effect of this interference is lessened by locating the ground radio communication stations far from industrial plants, lighting networks, highways, etc., and by the use of special electrical and radio devices for suppressing the interference mainly at the source of its generation. Certain kinds of industrial radio interference can be suppressed at the point of reception.

INERTIAL ACTUATORS of orientation systems. Devices producing control torques due to solid or liquid masses moving within the spacecraft thus giving rise to reactive forces. Solid moving masses (see GYROSCOPIC STABILIZERS, REACTIVE GYRATING MASSES) are the most commonly used. An advantage of inertial actuators is that their operation does not require the consumption of spaceborne working fluid. On the other hand, such actuators are unable to oppose external DISTURBING MOMENTS applied to the space-

craft for a long period of time and have to be used in joint with other types of actuators (e.g., attitude control motors or electromagnetic actuators) for providing a system of orientation capable of long-term operation.

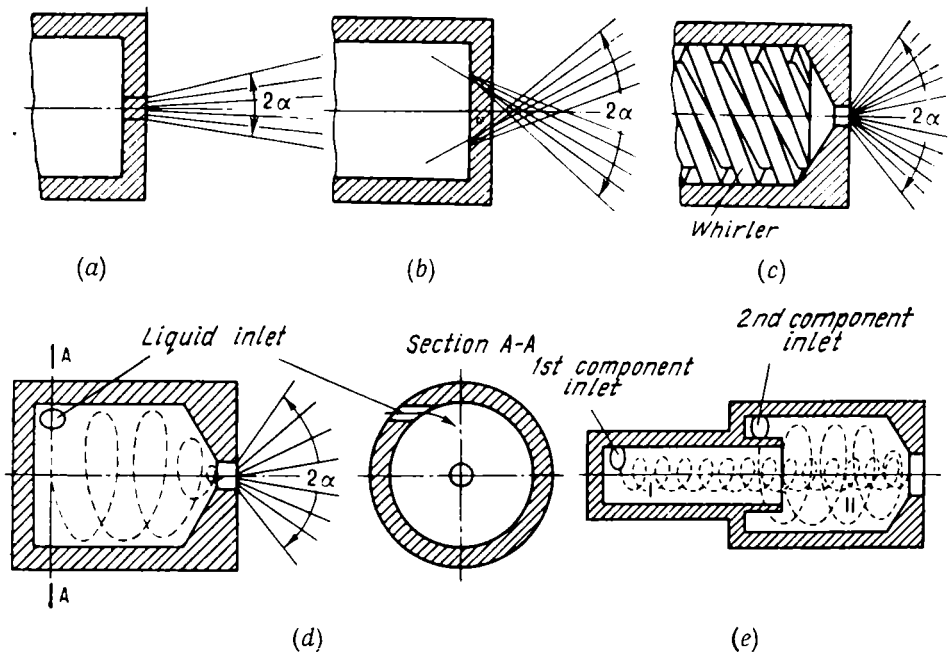
INERTIAL LOADS. Loads upon the structural members of space vehicles in accelerated motion. The inertial loads depend on the magnitude and direction of the acceleration. The overload components acting along the three rocket axes give the values of longitudinal and transverse acceleration factors.

INERTIAL NAVIGATION. A method of navigation according to which the velocity and position of the spacecraft are determined by acceleration measured by means of ACCELEROMETERS mounted either directly on the spacecraft or (in the case of a high-accuracy system of navigation) on a STABILIZED PLATFORM carried by the spacecraft. Besides accelerometers LINEAR ACCELERATION INTEGRATORS may also be used. This method of navigation has the advantage of being fully independent and enabling quick determination of the spacecraft position, its disadvantage is the gradual accumulation of error in speed and position estimation which limits the period of time in which this method can be employed.

INHIBITOR. A substance that retards or hinders undesirable chemical reactions, e.g., oxidation of fuel during storage, metallic corrosion, etc. Inhibitor for solid-propellant charges is a coating on a solid-propellant charge employed to protect certain areas whose burning is to be prevented. Polymeric materials are used for the coating. Heterogeneous propellants are sometimes inhibited by coatings made of polymeric binders with inactive fillers. Inhibiting propellant charges designed for long-term burning is a matter of difficulty which becomes even more so when the inhibitor is to serve as a binding layer.

INJECTOR of rocket engine. An element of the injector head for injecting, atomizing and mixing the propellant components in the combustion chamber and gas generator of a liquid-propellant engine. Depending on the state of aggregation of the propellant, injectors are classified as liquid, gas, gas-liquid, etc. To obtain a thorough mixing the injectors should ensure the specified level of atomization and distribution of propellant components in the combustion chamber volume. By design, injectors are classified as spray, swirl, and spray-swirl ones. SPRAY INJECTORS are bodies with openings drilled in them. They can produce one single jet or a number of jets of propellant. To improve atomization and mixing, multi-jet spray injectors frequently provide for an impingement of jets. In swirl injectors, the pressure-fed propellant component is swirled, injected into the chamber and, under the influence of centrifugal forces at the outlet of the injector, forms a so-called atomization flare which has the form of a thin conical film that rapidly disintegrates into drops. The propellant can be swirled by means of a whirler with a screw thread or by tangentially feeding the propellant into the injector. The spray-swirl injectors are a combination of the two types.

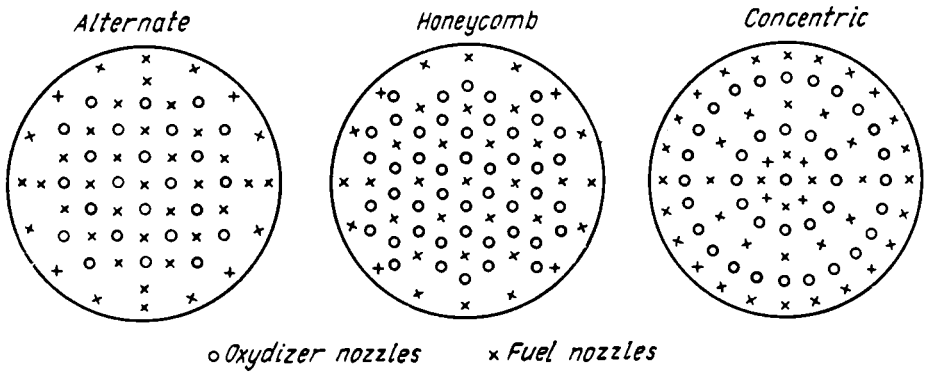
There are single-propellant and bi-propellant injectors. The former serve to inject one of the propellant components into the combustion chamber,



Injectors of several types: (*a*) spray injector ($2\alpha = 10° - 15°$); (*b*) impinging injector; (*c*) whirler-type swirl injector ($2\alpha = 50° - 110°$); (*d*) swirl injector with tangential propellant feed ($2\alpha = 50° - 110°$); (*e*) two-component swirl injector with propellant premixing.
The nature of the flux shown is for a liquid jet in a medium with zero counterpressure.

while the latter are units consisting of two aligned injectors for fuel and oxidizer. Bi-propellant injectors can be with an outer and inner mixing of components (in the latter case mixing takes place in a special mixing chamber). Apart from the main injectors, pilot burners are sometimes used to start rocket engines.

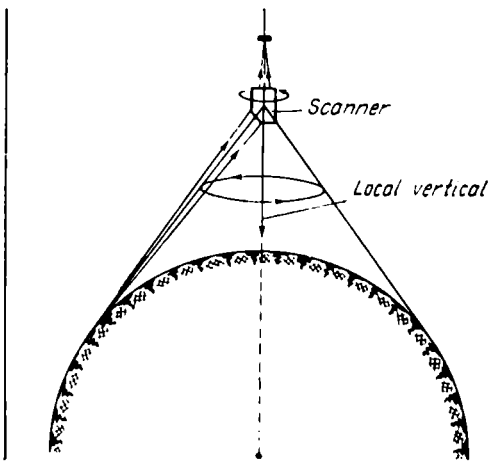
INJECTOR HEAD. The head of the combustion chamber or gas generator of a liquid-propellant engine with injectors for spraying, atomizing and mixing liquid propellant (see MIXING SYSTEM). There are flat, domed, and spherical injector heads. Widely used are flat injector heads with 3 plates



(inner, middle and outer) which form cavities with oxidizer and fuel. Injector heads are usually mounted on the inner and middle plates, the outer plate being a spherical segment. The quality of MIXING is determined by the design of injector heads and their spacing. The positioning of injectors should also ensure the protection of the inner walls of the engine and gas generator against overheat and burnthrough, as well as a convenient separate feed of the propellant components. Bi-propellant injector heads are usually located along concentric circles while single-propellant ones, in a staggered or honeycomb pattern with a transition to concentric circles near the periphery of the head.

INFRARED INSTRUMENTATION of meteorological satellites. Instruments carried on board the meteorological satellite to obtain IR pictures of the Earth for study of cloud pattern, ice distribution and thermal irregularities of the Earth's surface. In order to minimize distortions introduced by atmospheric absorption of IR radiation from the Earth's surface or from clouds, the range of spectral sensitivity of the spaceborne IR instruments is limited to the atmospheric water vapour windows. For the *Nimbus* meteorological satellite, use was made of the window in the 3.5—4.2 μ wavelength range. The instruments on *Cosmos-122* operated in the wavelength range of 8—12 μ and thus permitted IR pictures of the Earth to be taken on both the sunlit and the dark hemispheres. If an IR radiometer is included, its measurements may be used to determine the TEMPERATURE OF UNDERLYING SURFACE or the temperature and height of the upper boundary of the cloud cover.

INFRARED REFERENCE VERTICAL. A rocket-borne vertical line plotter whose operation is based on recording the thermal radiation of a planet in the IR spectrum. The vertical is defined as the direction towards the centre of the disc of the planet as seen from the spacecraft in the IR rays; the boundary of the disc is recorded along the circumference and at individual points of the disc with the aid of scanning devices and devices that focus the heat radiation flux of the planet on an IR sensing element (see Fig.). Since the IR vertical plotter is susceptible to the natural radiation of the planet, its operation does not depend on whether the disc of the planet viewed from the spacecraft is illuminated by sun rays.



IN-ORBIT ASSEMBLY. Soft approach and joining (assembly) of the spaceship or its components performed automatically or under the control of the crew. The main goal of in-orbit assembly is to build up large satellites and interplanetary spaceships out of separate units launched one after another into a circumterrestrial orbit. This method of assembly was suggested by K. E. Tsiolkovsky.

INSPECTION (in outer space). An inspection carried out at a short distance from the spaceship in order to establish whether any repairs are required.

INSTABILITY OF BURNING in solid-propellant engines. Intermittent burning and abnormal burning are encountered. The frequency of pulses in intermittent burning can be either low or high (see SELF-EXCITED VIBRATION). Characteristic of the low-frequency type are simultaneous pressure pulses in all the volume of the combustion chamber at a frequency of the order of tens of c/s. HF pressure oscillations occur when acoustic frequencies are spontaneously excited in the combustion chamber. Practically, frequencies of 200—50,000 cps are encountered. HF oscillations with a sufficiently developed amplitudes may lead to dangerous vibration of the structure, to an increase in heat transfer to the walls of the combustion chamber, and to burn-throughs. In addition, the mean pressure deviates from the rated pressure and a secondary pressure peak appears, which can exceed the rated pressure by several times and usually results in case destruction. Abnormal burning is the acyclic spontaneous starting and cutting off of the solid-propellant engine at intervals from several seconds to several minutes. This type of instability of burning is most often observed in case of burning of homogeneous propellants in the region of low pressures.

INSTRUMENT COMPARTMENT. A spacecraft compartment designed to accommodate radio, electronic, and electrical equipment, scientific instruments, power sources, etc. On spaceships, this is usually an air-tight section filled with a neutral gas (nitrogen) at a pressure near 1 at. This provides for the most favourable operating conditions of the instruments. A stable temperature is maintained within the compartment by the temperature control system.

INSTRUMENT FRAME. The structural member on which the spacecraft instrumentation and equipment are mounted. It is usually constructed of light alloys (aluminium or magnesium based) and is arranged in the instrument compartment or in the spaceman's cabin. By mounting the instruments and equipment on a framework, better access is provided to them. This also permits them to be subjected to an overall checkout prior to mounting the entire assembly in the spacecraft.

INTEGRAL TANKS. Rocket propellant tanks whose side walls serve at the same time as the external shell of the propellant compartment and carry the external longitudinal loads and bending moments acting thereon. In a number of instances the use of integral tanks allows a considerable reduction of the structural weight of the rocket, as the necessity of an external airframe of the propellant compartment is eliminated. Usually, integral tanks are pressurized, after which they possess high strength and rigidity. In the areas of bulkhead attachment, the cylindrical shells of the integral tanks transform into structural skirts with butt frames for joining the tanks with one another and with other bays of the rocket. Integral tanks are usually made of aluminium alloys.

INTEGRATING GYROSCOPE. A gyro having 2 degrees of freedom with respect to its base and provided with a damper that integrates the gyroscopic moment arising at rotation of the base. Floated integrating gyros are most widely used. Their main application is as highly sensitive sensors

of angular position mainly for installation of GYROSCOPE-STABILIZED PLATFORMS. A great number of up-to-date high-accuracy gyros, having a drift of $\leqslant$0.1 angular degree per hour, are basically floated integrating gyros.

INTELSAT. The name of a series of communications satellites and systems of space radio communications developed by Comsat Corp. for radio-telephone communication and relaying of TV broadcasts. *Intelsat* satellites are injected into stationary orbits; they are spin-stabilized; energy is supplied by solar batteries. *Early Bird*, the first in this series, was sent up on April 6, 1965, to hover above the Atlantic Ocean; its weight in orbit is $\sim$39 kg; it is part of the *Intelsat-1* communication system. The *Lany Bird-2*, launched on January 11, 1967, to hover over the Pacific, and *Canary Bird*, launched on March 22, 1967, over the Atlantics (each weighs 87 kg in orbit), are used in the *Intelsat-2* communication system. Earth satellites are being developed for the *Intelsat-3* and *Intelsat-4* systems. Receiver-transmitter stations of the *Intelsat* system are located in the USA, England, France, the GFR, Italy, Japan, and other countries.

INTERCEPTION. The method of approach of 2 space bodies, which presumes the specification of only one factor, i.e., the distance between them at their closest approach, whereas their relative velocity is not taken into consideration. Military application of interception is for destroying an enemy-launched spacecraft.

INTERCONTINENTAL BALLISTIC MISSILE (ICBM). A ballistic combat missile that can be launched from one continent to another. The flight range is 8—12 thou. km or more.

INTERCOSMOS. The system embracing countries collaborating with the Soviet Union in space research and its peaceful uses. This co-operation is based on bi-lateral and multi-lateral agreements. Collaboration in this field has developed steadily since 1957, when joint observation of early Soviet satellites was undertaken in various countries. Subsequently, these efforts grew into multi-lateral co-operation of the academies of sciences of the socialist countries in complex programmes for Global Geophysical Exploration and Research by Observation of Artificial Earth Satellites. The latter, in particular, envisaged the INTEROBS basic visual synchronous observation of satellites to study transient variations in atmospheric density. On November 15—20, 1966, in Moscow, a conference of representatives of socialist countries adopted an agreement on broad co-operation of their countries in peaceful exploration and use of space. This agreement is aimed at expansion of the relevant fields of research in the signatory countries and solution of numerous practical problems of the national economy, culture and other fields of endeavour. The socialist countries, including the People's Republic of Bulgaria, the Hungarian People's Republic, the German Democratic Republic, the Republic of Cuba, the Mongolian People's Republic, the Polish People's Republic, the Socialist Republic of Roumania, the USSR, and the Czechoslovak Socialist Republic adopted a programme of co-operation at a conference held in Moscow on April 5—13, 1967. The programme covers exploration of the physical properties of space and the upper atmosphere, satellite meteorology, space communication, space biology and medicine, launching of satellites and rockets, holding of con-

ferences, symposia and meetings, and exchange of visits of scientists. On August 13, 1968, the signatories to the agreement submitted to the UN Secretary General a draft plan for an *INTERSPUTNIK* commercial system of international space communication that would meet the requirements of both developed and developing countries. The *Cosmos-261* was the first spacecraft launched according to this programme; it was placed in orbit on December 20, 1968, to make experiments in exploration of the upper atmosphere of the Earth and the nature of aurorae. Alongside joint use of satellites orbited by the Soviet Union according to its national programmes, beginning with 1969 the co-operation programme envisages the launching of satellites and geophysical rockets bearing the scientific experiment of other socialist countries.

International Astronautical Federation

On June 30, 1966, the USSR and France signed an agreement on co-operation in the field of scientific investigation of space, space communication, space meteorology and aeronomy. According to this agreement, work has been undertaken to establish colour TV communications between Paris and Moscow via the *Molniya-1* satellites, Soviet rockets are to carry French instruments and French rockets are to carry Soviet instruments, and the French *Roseau* radio-astronomy satellites are to be launched by Soviet rockets.

Council for International Co-operation in Space Exploration and Use (chairman, Academician B. N. Petrov) of the Academy of Sciences of the USSR is the co-ordinating body of the *Intercosmos* system.

INTERMEDIATE ORBIT. An orbit different from the Keplerian (see UNDISTURBED MOTION) and closer to the true orbit actually described by a celestial body. It is used in celestial mechanics mainly in cases when the Keplerian orbit differs substantially from the true one and does not yield the desirable approximation in the determination of the true orbit.

INTERNATIONAL ACADEMY OF ASTRONAUTICS (IAA). A body established by the International Astronautical Federation (IAF) in 1960. Members of the IAA are elected from among scientists and engineers prominent for their contribution to space flight. The aims and functions of the IAA are to promote the development of space flight, conduct research work, and gather scientific conferences; the IAA publishes the *Astronautica acta* magazine and awards medals and prizes. The Academy incorporates three sections: basic sciences (180 members according to Charter), engineering sciences (180 members) and life sciences (135 members). Meetings of the IAA are called once every 2 years at the time of congresses of the IAF. The IAA includes following sub-committees: Awards and Fellowships; History of Astronautics; International Lunar Laboratory; Space Relativity; Publications; Space Law Liaison.

INTERNATIONAL ASTRONAUTICAL FEDERATION (IAF). An international scientific non-governmental and non-commercial organization. Founded in 1950 by representatives of 11 national societies. By 1965 the number of member-societies increased to 49 (50,000 persons in 33 countries). The managing body of the IAF is the General Assembly which meets annually during the IAF Congress and elects a Bureau, composed of the President and four Vice-Presidents. The IAF has a Committee for Bioastronautics and

Inter-

national exhibition on cosmonautics

a Committee for Education. In 1960 the IAF founded an INTERNATIONAL ACADEMY OF ASTRONAUTICS and an International Institute of Space Law. The IAF publishes the transactions of all scientific conferences and congresses sponsored by it. The tasks of the IAF are: to promote the development of space flight for peaceful purposes; to help widely popularize information on space exploration; to stimulate and maintain public interest in space exploration; to encourage space research through international and national research centres, universities and companies; to promote vigorous research activities at academies, institutes and commissions in all branches of space sciences; to convene international congresses, symposia, colloquia and other scientific conferences; to cooperate with appropriate international and national organizations in all fields related to exploration and peaceful uses of outer space.

INTERNATIONAL EXHIBITION ON COSMONAUTICS. Was held in Moscow in April—June, 1927. It was organized by the Association of Inventors with the object of pooling the efforts of scientists working in the field of rocket engineering and to disseminate the idea of interplanetary flights. The exposition reflected the science-fiction, theoretical, and invention-and-design stages in the development of rocket engineering, as well as the latest advances in astronomy and meteorology and means of interplanetary communication then under development. Among the exhibits were works of Russian and Soviet scientists N. I. KIBALCHICH, K. E. TSIOLKOVSKY, F. A. TSANDER, inventors A. Ya. Fyodorov, G. A. Polevoy, G. E. Krein, and foreign scientists W. HOHMANN, F. ULINSKY, H. OBERTH, M. VALIER, R. ESNAULT-PELTERIE, R. GODDARD.

INTERNATIONAL GEOPHYSICAL YEAR (IGY). An international scientific project carried out jointly, after agreed programmes, by scientists of many countries of the world from July, 1957, to December, 1958. The principal task of the IGY was comprehensive study of the influence the solar activity exerts on various phenomena observed in the lower and upper layers of the atmosphere, the ionosphere, and the near space. Accordingly, the time selected for the IGY corresponded to the forecasted period of maximum solar activity. Owing to the existence of a network of observation station at various longitudes and latitudes, the Sun was under continuous observation around the clock. In cases of peak solar activity, the observation stations radioed to a special centre which sent an alarm to all scientific centres, institutes and observatories conducting studies under the IGY programme. Along with conventional ground observation methods and balloon soundings, extensive studies with the aid of rockets were carried out during the IGY. Of particular value were the first launchings of artificial Earth satellites carrying scientific instruments. During the IGY many phenomena were studied which shed light on the mechanism of the solar-terrestrial links, and fundamentally new discoveries were made concerning phenomena in the upper layers of the atmosphere and near space. Most important for manned space flight was the discovery of radiation belt of Earth on the basis of measurements made by satellites. The studies were continued into 1958—59, called the International Geophysical Cooperation Year (IGCY).

INTERNATIONAL QUIET SUN YEAR (IQSY). An international scientific project carried out in 1964—65, at the time of forecasted minimum of solar activity. The object of the programme was to investigate the influence of the Sun on geophysical phenomena in the absence of any formations on the solar disc, and detailed investigations of the influence exerted on the Earth by specific kinds of activity, because during minimum activity periods individual manifestations of solar activity (spots, chromospheric flares, etc.) are observed isolated from other manifestations. Similarly to the IGY, the IQSY programme comprised studies of the Sun, the ionosphere, geomagnetism, cosmic rays, luminescence of the sky and aurorae polares, the properties of the Earth atmosphere and of near space. Near-space investigations were carried out with the help of numerous Earth satellites, space probes, automatic interplanetary stations and high-altitude geophysical rockets.

INTERPLANETARY MEDIUM. The matter filling interplanetary space. It consists of solid bodies and particles moving round the Sun, ions and electrons moving in all directions from the Sun; the interplanetary medium is also traversed by the nuclei of various atoms (cosmic rays) arriving with great velocities from the GALAXY. Solid bodies of the interplanetary medium (from several km to a few μ in size) are formed in disintegration collisions of minor planets. The chief source of minute particles and dust is the disintegration of the nuclei of COMETS. With the exception of the larger bodies (asteroids), the solid component of the interplanetary medium goes by the name of *meteoric matter* (see METEORS). Near the Earth's orbit the mean distance between particles larger than 1 mm is several km; for this reason, the meteoroid hazard in space flight is slight; the average rate of particles larger than 1 mm colliding with a surface of 1 m^2 is one per several tens or even hundreds of years. Impacts of minute particles of a size of the order of 10^{-4} cm occur 10^9—10^{12} times more frequently: from once every few minutes to several times a second. In a few particularly dense swarms, the frequency of impact may increase thousands of times. However, a spaceship should take only a few hours (at the most, a few days) to traverse the denser portion of a swarm (moving crosswise through the stream). The bulk of the solid bodies and particles of the interplanetary medium are in motion about the Sun and are concentrated near the plane of the ECLIPTIC.

The orbits of the smaller particles gradually diminish due to the light pressure of the Sun; this results in an increase in the density of the dust component closer to the Sun. The sunlight that is reflected and scattered by dust particles creates an extremely faint luminosity along the ecliptic and is called the zodiacal light. Dust particles of the interplanetary medium may be electrically charged; then they are influenced by the interplanetary magnetic field in addition to solar gravitation. For a long time it was thought that the interplanetary medium included gases revolving about the Sun. However, it was found that the corpuscular streams of the Sun, i.e., fluxes of ionized atoms (principally protons, or hydrogen nuclei), sweep up all the gases from interplanetary space. Besides ions, corpuscular streams include electrons, and these two types of particles together form the elec-

trically neutral solar plasma that is constantly flowing out in all directions from the outer portions of the solar corona, thus producing the so-called solar wind. In the vicinity of the Earth's orbit the solar wind has a density of 5 to 10 particles per cm^3 moving with velocities of 300—600 km/s. During solar flares, the flare portion of the Sun's surface ejects corpuscular streams of enhanced density (up to 200 ions in 1 cm^3) moving at velocities of up to 2000 km/s. These streams are directed along the lines of force of the interplanetary magnetic field; the lines of force are not radial but have the shape of a slightly twisted spiral. A few ions moving at velocities of tens of thousands of km/s form the solar component of cosmic radiation. The Earth's surface is protected from the effects of the interplanetary medium by the atmosphere and the Earth's magnetic field.

INTERPLANETARY SPACE. The region of space extending to the limits of the outermost planetary orbit (that of Pluto at the present time). Interplanetary space is not an absolute vacuum (see INTERPLANETARY MEDIUM). In addition to gravitational, magnetic and electrostatic fields, interplanetary space is permeated with electromagnetic and corpuscular radiation of celestial bodies, principally the Sun. The temperature of interplanetary space is the temperature of a small absolutely black sphere at a given distance from the Sun. At the Earth's distance from the Sun it is 216°K.

INTERPLANETARY TRAVEL. See COSMONATICS.

INTERPLANETARY TRAVEL STUDY GROUP. (1) A body founded under the auspices of the Military Research Society, Air Force Academy, Moscow, in April, 1924, by V. P. Kapersky, M. G. Leiteisen, and M. A. Rezunov. The group sponsored a series of lectures, maintained correspondence with K. E. TSIOLKOVSKY; actively participated in the foundation of the SOCIETY FOR STUDYING INTERPLANETARY TRAVEL. (2) A body founded under the auspices of Leningrad Transport Institute in late 1928 under the chairmanship of Dean of Faculty of Aeronautics N. A. RYNIN; consisted of faculty members, engineers and students. Was instrumental in preparation of the first space encyclopaedia, *Interplanetary Travel* by N. A. Rynin. (3) A jet engine study group directed by F. A. Tsander was formed in early 1931 under the auspices of the Central Council of Society for Assisting Defence and Aviation and Chemical Construction in the USSR (Osoaviakhim), Moscow. In the 2nd half of 1931 the body was reorganized into the Moscow Group for Study of Reactive Motion.

INTERSTELLAR COMMUNICATION. Unilateral or bilateral exchange of information between civilizations inhabiting different planetary systems. The following possibilities of interstellar communication were considered: by radio (probably in the range of wavelengths of 3 to 30 cm), by optical means (laser ray), or by sending robot probes to other systems. Radio seems the most probable means of interstellar communication. This implies transmission of information at low rate as signals in the form of relatively long pulses of a quasi-sinusoidal carrier frequency which, for easier detection, may confirm to a natural standard (e.g., the frequency of the hydrogen spectral line at the 21-cm wave-length), and information transmission at high rate, over a wide range of frequencies. With technical facilities correspond-

ing to the modern level of terrestrial civilization, the first kind of interstellar communication could be established at distances of the order of tens and hundreds of parsecs (10^{20}—10^{21} cm). Interstellar communication at high rates of information transmission requires energy resources far surpassing the modern terrestrial level. Studies of the interstellar communication problem are concentrated on developing of methods for detecting intelligent signals (e.g., finding radio sources with very small angular dimensions or peculiarities in a spectra); designing equipment for the detection of weak narrow-band signals against strong background noise; and discussing methods for distinguishing intelligent signals from natural cosmic radiation as well as the methods for their decoding. Attempts, so far unsuccessful, were made to detect radio signals of interstellar communication from some near stars (ε Eridani and τ Ceti) and also to analyse "for artificiality" some cosmic radiosources with peculiar spectra (see LINCOS, OZMA PROJECT).

INTERSTELLAR MEDIUM. Gas (mainly hydrogen) with a mean density of 10^{-24} g/cm^3, particles of cosmic dust of a size of $\sim 10^{-5}$ cm with a mean density of distribution in space equal to 10^{-26} g/cm^3, cosmic rays with a mean energy density of $\sim 10^{-12}$ erg/cm^3 in the interstellar magnetic field with a mean intensity of 10^{-6} oe. The interstellar medium is divided into regions of almost totally ionized hydrogen with a temperature of about 5000°—10,000°K located near hot stars, and regions of un-ionized hydrogen at ~50°—100°K, the temperature being still lower in denser regions. The interstellar medium is of a nebulous flocculent structure. The masses of medium-size nebulae are several times that of the Sun and their density is approximately ten times higher than the mean density of the interstellar medium. In many places of the Galaxy, these clouds form part of enormous gas-dust complexes whose masses are tens and hundreds of thousands of times that of the Sun. The interstellar medium is concentrated in the plane of the Galaxy forming a layer about 100 to 200 parsecs thick in the central portion and expanding by one order of magnitude towards the periphery. The space between galaxies is filled with a medium whose density is 4—5 orders of magnitude less than that of the interstellar medium.

INVARIABLE LAPLACE PLANE. A plane, in the PROBLEM OF n BODIES, perpendicular to the angular-momentum vector of the system. Since the magnitude and direction of the angular momentum of a system of n material particles is constant, the plane will maintain an invariable position in space.

ION-EXCHANGE RESINS. A mixture of compounds of high molecular weight capable of ion exchange, and characterized by high absorptive power, mechanical strength, chemical stability and extremely hydrophylic nature. Ion-exchange resins are used in WATER REGENERATION systems for desalinization, and in the systems for purification of condensed atmospheric moisture for elimination of organic matter and unpleasant odours.

IONIZING RADIATION DOSES. Three categories of ionizing radiation doses have been established that permit space flight without serious radiation injury of the organism. This has been done on the basis of experimental and clinical data on the biological effects of various types of ionizing radiation. The doses take into account the relative biological effect, time rela-

tions, effects of extremum factors of non-radiation origin, as well as a certain degree of compensation for disturbed functions in the irradiated organism.

The *permissible dose* produces no noticeable somatic disturbances in man at any time throughout his life. It has been established for specifying the unavoidable exposure of spacemen to cosmic radiation emitted by the Galaxy and the RADIATION BELT OF EARTH. In flights lasting for up to 30 days this dose should not exceed 15 rem. The *dose of justifiable risk* may only cause rare cases of minor clinical manifestations of irradiation reaction. This dose is established for specifying probable irradiation (e.g., radiation from solar chromospheric flares).

Critical dose is a dose of ionizing radiation causing marked clinical manifestation of radiation injury, but not death. For flights lasting up to 30 days this dose should not exceed 125 rem.

IONOGRAM. See IONOSONDE.

ION ORIENTATION SENSOR. A position pickoff of certain systems of satellite orientation, susceptible to the counterflow of charged particles (ions) in the upper atmospheric layers of the planet orbited by the satellite. This sensor determines the angular deviation of one of the satellite's axes from the direction of the flow of ions.

IONOSONDE. A radio instrument for determining the effective height of reflection of radio waves from the IONOSPHERE at fixed frequencies or in a continuous range of frequencies, the critical frequencies of the ionosphere and the height distribution of electron concentration. It consists of a high-frequency pulse transmitter, a receiver, a cathode-ray indicator, synchronizing and calibrating devices, and power sources. The master oscil-

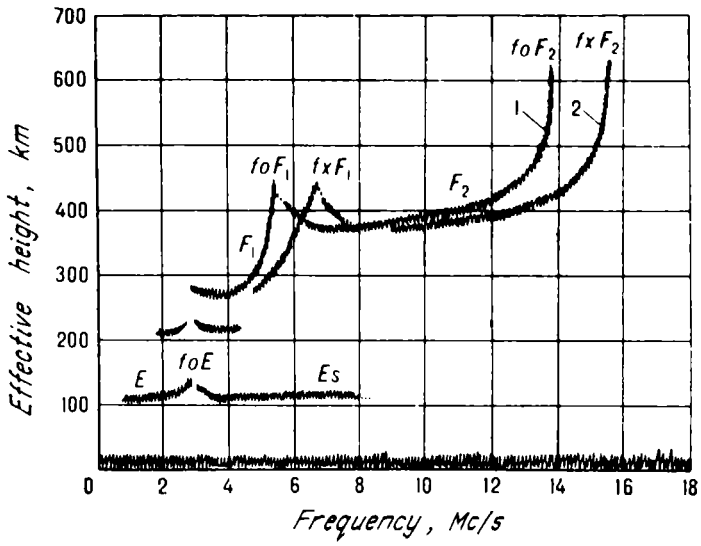


Fig. 1. Ionogram obtained with the aid of panoramic ground-based ionosonde.
1—ordinary wave; *2*—extraordinary wave.

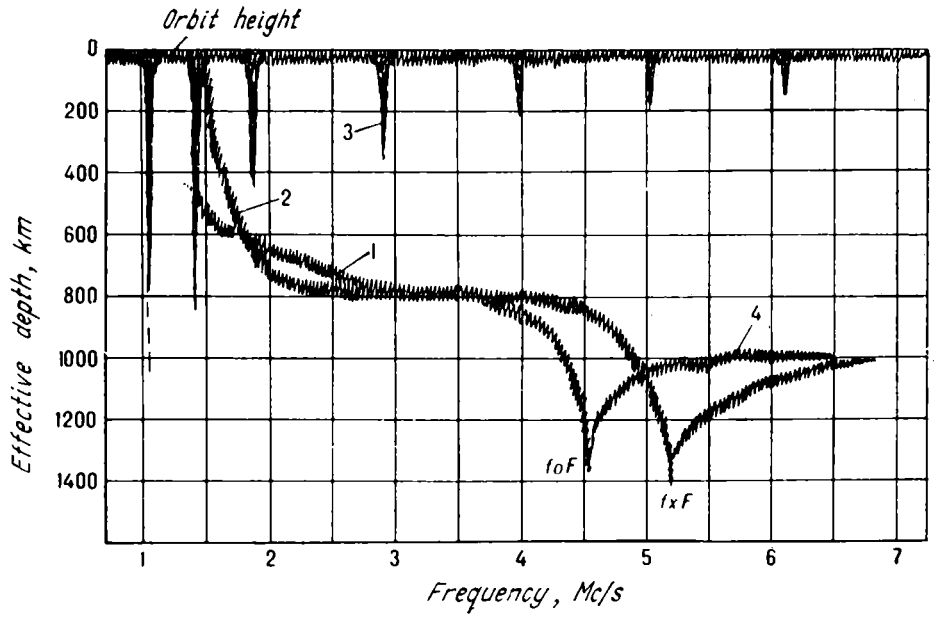


Fig. 2. Ionogram obtained with the aid of ionosonde placed on satellite.
1—ordinary wave; *2*—extraordinary wave; *3*—plasma resonance; *4*—Earth level.

lator of the transmitter is usually the heterodyne of the receiver which permits balanced tuning of the receiver and transmitter. Most commonly used are panoramic ionosondes wherein the master oscillator continuously changes the transceiver frequency in the range of 1 to 20 Mc/s within 10—30 s, whereupon an ionogram or the so-called altitude-frequency response of the ionosphere appears on the indicator screen (Fig. 1).

The height to the reflecting region of the ionosphere is determined from the time lag of the reflected signal with respect to the emitted signal, assuming that all along the path the radiowaves propagate with the speed of light. This, instead of the true, gives the apparent height of reflection, i.e., the effective height, because the speed of propagation of radio waves in the region of reflection is less than the speed of light and depends on the refractive index of the IONOSPHERE.

Ground-based ionosondes can analyse the lower part of the ionosphere up to its chief maximum. For investigating the outer ionosphere (above 250—300 km), ionosondes are placed on satellites with a sufficiently high orbit. An ionogram thus obtained is shown in Fig. 2. Methods have been developed for converting effective height to actual, i.e., for obtaining the actual height distribution of electron concentration.

IONOSPHERE. The upper part of the atmosphere which begins at altitudes where an appreciable content of free charged particles (electrons and ions) appears. The ionosphere is ionized primarily by the ultraviolet radiation and X-rays of the Sun. Its ionization is also greatly affected by particle fluxes invading the Earth's atmosphere from the near space. In the daytime the bottom of the ionosphere lies at 50—60 km, at night, at 80—85 km.

According to the modern concept, the upper boundary of the ionosphere may be referred to altitudes of about 18—25 thou. km. The Earth's influence on its gaseous envelope gradually vanishes at higher altitudes, and the ionosphere changes into interplanetary plasma which exists in the free state beginning at about 70—80 thou. km from the Earth.

The ionosphere is usually regarded as quasi-neutral plasma, i.e., its electron and ion contents are assumed to be equal. Since up to now no sufficiently definite data are available indicating a difference between the ionospheric plasma and neutral plasma, the ionosphere is primarily characterized by its electron density N (electrons per cm^3) varying with height Z. The electron density depends also on the latitude and longitude, i.e., it is geographically distributed, it varies continuously with time and shows daily variations, which in turn depend on the season of the year and the cycle of solar activity. Along with these slow variations of the ionosphere, there are rapid variations of the electron density both with time and from point to point; heterogeneous ionized formations occur and vanish there continuously; they are various in size and move at different velocities (see WINDS IN IONOSPHERE). Thus the behaviour of the ionosphere is described in the terms of mean statistical characteristics.

The dependence of electron density on height $N(Z)$ has, on the average, the following features. Beginning from the bottom of the ionosphere the electron density generally increases and at $Z_m \approx 250—400$ km reaches the maximum value N_m which, under different conditions, lies between $2 \cdot 10^5$ and $5 \cdot 10^6$ electrons per cm^3. This is the primary maximum of electron density of the ionosphere which is often called the maximum of F region, or layer, and denoted by N_mF_2. The part of the ionosphere below the altitude of the N_mF_2 peak is the lower ionosphere; the part of the ionosphere above Z_m is the outer ionosphere. Different authors use different terms for the outer ionosphere: protosphere, protonosphere, EXOSPHERE, MAGNETOSPHERE, plasmosphere, geocorona. The general dependence of electron density on height in the lower and outer ionosphere is shown in Fig. 1.

The lower ionosphere, in turn, is divided into several regions. The region at heights from 50—60 km to 80—85 km, where the ionosphere exists only in the daytime, is called the D region, or layer; the maximum electron density there is $(2—5) \cdot 10^3$ electrons per cm^3. Slightly marked maxima of N at 65—75 km are occasionally observed in the D region. The D region is a multicomponent part of the atmosphere; it consists largely of ionized molecules of oxygen (O_2^+) and nitrogen oxide (NO^+). Therefore ionization and recombination processes here are more complicated than in other parts of the atmosphere. In the D region, where the density of neutral particles n varies within approximately 2 ($10^{16}—10^{14}$) cm^{-3}, the degree of ionization is still rather low ($n/N \approx 10^{11} — 10^{13}$). The collisional frequency between electrons and other particles ν s^{-1} in the D layer is high, approx. $10^8—10^6$ s^{-1}; this is the reason for strong absorption here of medium and short radio waves reflected by the ionosphere (see IONOSPHERIC REFLECTION OF RADIO WAVES). For long and, especially, very long radio waves the D region is a reflecting wall which, together with the Earth's surface, forms a spherical waveguide, thus providing for good propagation of these waves

along the Earth's surface. A stable maximum of electron density is regularly formed above the D region of the ionosphere, at 100—110 km; this ionospheric region, at heights of 90—120 km, is the so-called E layer where the maximum electron density is $N_m \approx (1—3)\cdot 10^5$ electrons per cm^3.

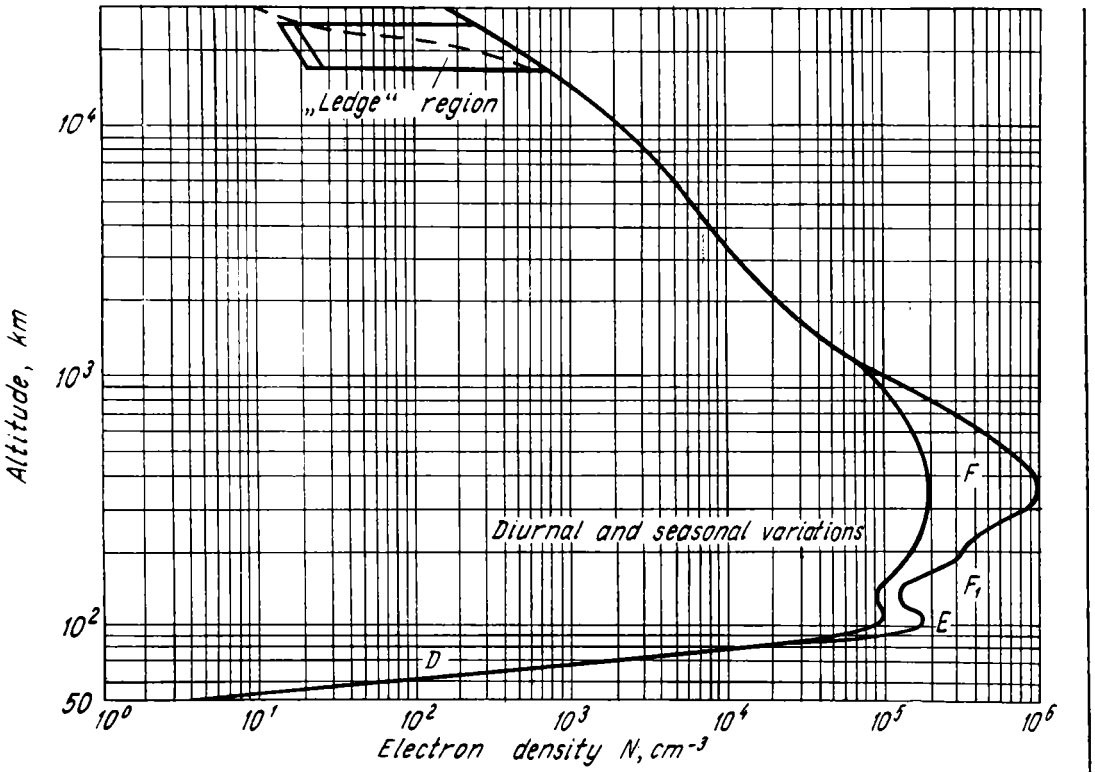


Fig. 1. General dependence of electron density on altitude in the lower and outer ionosphere.

A pronounced sporadic E layer, only 1—2 km thick, is occasionally produced at the same altitudes, where the electron density reaches $(7—8)\cdot 10^5$ and even 10^6 electrons per cm^3. The E region consists largely of ionized molecules of oxygen (O_2^+) and nitrogen oxide (NO^+). The ionospheric region above the E region is called the F region; at times, but chiefly during the day-time, an N peak at 180—200 km occurs in addition to the N_mF_2 peak. Therefore the F region of the ionosphere is divided into the F_1 and F_2 layers; $N_mF_1 \approx$ $\approx (2—6)\cdot 10^5$ electrons per cm^3 under different conditions. The F region consists largely of ionized oxygen atoms (O^+) and molecules (O_2^+). Diurnal and seasonal variations of the electron density at different levels in the lower ionosphere and near its primary maximum are shown in Figs. 2 and 3.

Ionized oxygen atoms (O^+) predominate, at first, in the outer ionosphere at $Z \approx 300—400$ km; in addition, there are ionized nitrogen atoms (N^+); and ionized helium (He^+) and hydrogen ions (protons H^+), appear. Further change in the ionospheric composition with height is as follows: the oxygen content gradually decreases, the nitrogen and helium contents remain low,

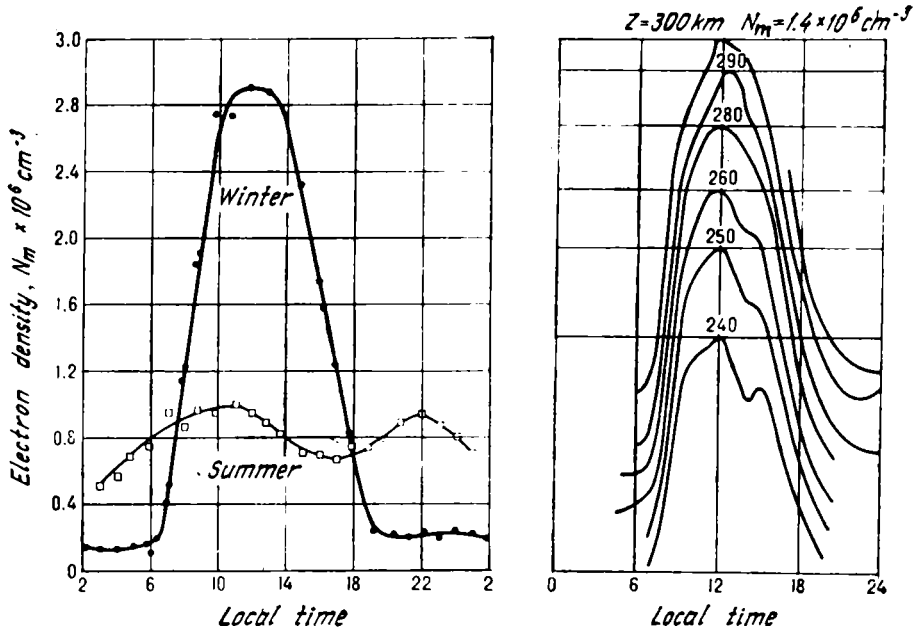


Fig. 2. Left: diurnal variations of electron density at the altitude of the primary maximum of the ionosphere, measured in Moscow in summer and winter of 1945. Right: diurnal variations of electron density at different altitudes in the *F* region, measured in Great Britain in January, 1950.

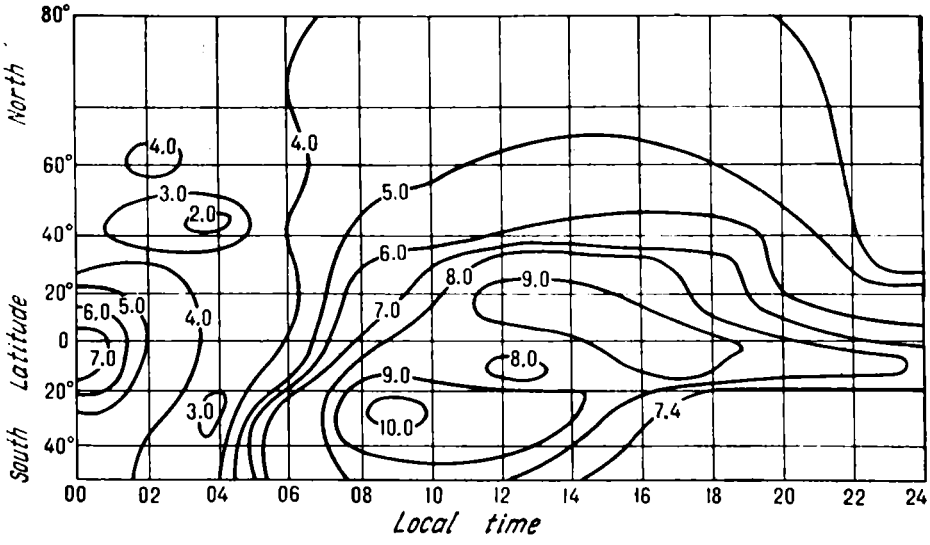


Fig. 3. Seasonal changes of electron density at maximum levels of various ionospheric regions, measured in Norway in 1933.

but the proton content increases rapidly. According to current data, the ionosphere above 1200—1400 km consists largely of protons, while the relative content of helium is about $(1—2)\cdot10^{-2}$. The electron density in the outer ionosphere slowly and monotonously diminishes with height (see Fig. 1); the electron density at $Z \approx 1000$ km is still high ($N \approx (5—10)\cdot10^4$ electrons per cm^3); at $Z \approx 10{,}000$ km, $N \approx (1—2)\cdot10^3$ electrons per cm^3. According to different sources, the electron density at $Z \approx (15—20)\cdot10^3$ km sharply falls at times (see ATMOSPHERIC WHISTLERS) and generally fluctuates between several hundred and 10—20 electrons per cm^3. Near the primary maximum the degree of plasma ionization is not high: the Earth plasma density is still rather low, the neutral particle density exceeds the electron density several hundred or even thousand times ($n/N \approx \approx 2\cdot10^3—2\cdot10^2$). But higher up the ionization degree rises rapidly and at 1200—1400 km $n \approx N$, and still higher up, at $Z \approx 10{,}000$ km, the relative content of neutral particles falls down to only one-tenth and less ($n/N \approx \approx 0.1—0.05$). At $Z \approx 10{,}000—20{,}000$ km, $n \approx 50$ particles per cm^3.

Temperature T of various particles, which determines their average thermal velocities and is the energetic measure of the near-earth plasma, is an important physical characteristic of the ionosphere. The average thermal velocity of ions v_i, in its turn, determines the velocity of ionosonic waves and indicates the ionospheric regions where the velocity V_0 of a spacecraft is greater than, comparable to, or less than v_i. It is on the ratio V_0/v_i, as well as on the mean free path of particles Λ designating the degree of plasma rarefaction, that the interaction of the spacecraft with rarefied plasma depends.

The values of all these parameters for some fixed altitudes of the ionosphere are given in the Table (p. 202). The Table shows that on the average the temperature increases rapidly with height: near the bottom of the ionosphere, $T \approx 300$°K; in the region of the primary maximum, $T \approx 1000°—2000$°K, i.e., the energy of a particle is about 0.1—0.2 eV. It has been established, however, that at 250—700 km the electron temperature may exceed the ion temperature 2—4 times. At 1000—1500 km, $T \approx 3000$°K. Increasing still further with height, the particle energy reaches about 0.5 eV ($T \approx \approx 6\cdot10^3$ °K) at $Z \approx 6000$ km, and at $(15—20)\cdot10^3$ km the temperature of charged particles corresponds to 1.5—3 eV. The Table also shows that at $Z \approx 800—1000$ km, v_i is always less or far less than the velocity of the spacecraft ($V_0 \approx 8\cdot10^5—10^6$ cm/s). Within 2000—6000 km, the velocity of spacecraft is comparable to ion velocities, and at $Z \approx 20{,}000$ km the ion velocity is higher or even considerably higher than the velocity of the spacecraft. The average thermal velocity of electrons v_e is considerably higher than V_0 throughout the ionosphere and varies within $10^7—10^8$ cm/s with height. In the region of the primary maximum of the ionosphere the collisional frequency for electrons $\nu \approx (1—2)\cdot10^3$ s^{-1} and the mean free path of ions and electrons $\Lambda \approx (0.5—2)\cdot10^4$ cm, i.e., in this region Λ substantially exceeds the size of the spacecraft. At 1000—2000 km the mean free paths are about 10 km and $\nu \approx 20$ s^{-1}. The values of Λ and ν essentially influence the nature of the phenomena taking place near a spacecraft moving through the ionosphere.

The structure of the ionosphere is also greatly affected by the permanent

MEAN VALUES OF MAIN PARAMETERS OF LOWER AND OUTER IONOSPHERE

Altitude Z, km	Concentration of neutral particles n per cm^3	Electron density N per cm^3		Temperature T, °K	Average thermal velocity of ions v_i, cm/sec	Electron collisional frequency ν, sec^{-1}	Mean free path of electrons Λ, cm	Geomagnetic field intensity in middle latitudes H_0, oersted	Precession radius of ions ρ_{hi}, cm	Precession radius of electrons ρ_{he}, cm
		diurnal	nocturnal							
60	$8\cdot10^{15}$	10^2	—	300	$5\cdot10^4$	$5\cdot10^7$	0.3	0.5	$3\cdot10^2$	1.3
80	$8\cdot10^{14}$	$2\cdot10^3$	—	180	$3\cdot10^4$	$2\cdot10^6$	5	—	—	—
100	$2\cdot10^{13}$	10^5	$2\cdot10^3$	230	$4\cdot10^4$	$2\cdot10^5$	$5\cdot10^1$	—	—	—
120	$3\cdot10^{12}$	$1.2\cdot10^5$	$2.5\cdot10^3$	320	$5\cdot10^4$	$2.5\cdot10^4$	$6\cdot10^2$	—	—	—
150	$6\cdot10^{11}$	$1.5\cdot10^5$	$6\cdot10^3$	450	$6\cdot10^4$	$3.3\cdot10^3$	$4\cdot10^3$	—	—	—
200	$5\cdot10^{10}$	$5\cdot10^5$	$3\cdot10^4$	600	$7.5\cdot10^4$	$2\cdot10^3$	$9\cdot10^3$	—	—	—
300	$3\cdot10^9$	$2\cdot10^6$	10^5	1,000	$9\cdot10^4$	—	—	0.43	$4\cdot10^2$	2
400	$5\cdot10^8$	$1.5\cdot10^6$	$5\cdot10^5$	1,500	$1.1\cdot10^5$	$1.5\cdot10^3$	$2\cdot10^4$	—	—	—
700	$6\cdot10^6$	$5\cdot10^5$	$2\cdot10^5$	2,000	$1.6\cdot10^5$	—	$1\cdot10^5$	—	—	—
1,000	$4\cdot10^5$	$1\cdot10^5$	10^5	3,000	$3.5\cdot10^5$	20	$8\cdot10^5$	0.33	$5\cdot10^2$	5
2,000	$2\cdot10^3$	$2\cdot10^4$	—	—	$7\cdot10^5$	—	—	0.22	—	—
3,000	10^3	$1\cdot10^4$	—	—	—	—	$3\cdot10^6$	0.16	—	—
6,000	$2\cdot10^2$	$4\cdot10^3$	—	6,000 (0.5) eV	$1\cdot10^6$	1	—	0.10	10^3	$2\cdot10^1$
10,000	10^2	$2\cdot10^3$	—	(0.8—2) eV	$1.5\cdot10^6$	—	—	—	—	—
20,000	$4\cdot10^1$	$3\cdot10^2$ (20)	—	(1.5—3) eV	$2\cdot10^6$	1	$3\cdot10^9$	0.01	$3\cdot10^4$	$7\cdot10^2$

geomagnetic field and its disturbances (see TERRESTRIAL MAGNETISM). Charged particles precess in the magnetic field and move along helix-like curves following magnetic lines of force. Electrons and ions rotate in opposite directions, and the radii of their circles $\rho_{he} = eH/mc$ and $\rho_{hi} = eH/Mc$ (see Table) differ from each other by the inverse ratio of their masses. The energy density of a magnetic field $H_0^2/8\pi$ exceeds the thermal energy density NkT of the particles 10^3—10^4 times. Therefore the magnetic field can be considered to be strong throughout the ionosphere; electrons and ions are said to be magnetized in this region of the near-earth plasma. The precession of electrons and ions makes the ionosphere an anisotropic birefrigent medium. This complicates propagation of electromagnetic waves in it. A radio wave splits in the ionosphere into two components—ordinary and extraordinary waves. The electric vectors of these waves form circles, rotating in opposite directions (the waves are circularly polarized). It follows that a single radio signal, incident on the ionosphere, is reflected from it as a signal doublet; the trajectories of short and medium waves (wavelengths between 10 m and 2—3 km) in the ionosphere become more complicated; variations in their amplitude (fading) as well as in the direction of their arrival (bearing) increase. Owing to the influence of the geomagnetic field, only one of the components, the extraordinary wave of long and very long wave-lengths (more than 5 km), reaches the outer ionosphere. The geomagnetic field also affects the interaction of a satellite with the ionosphere; the resulting effects essentially depend on the ratio of the linear dimension of the satellite to the radii of precession (Larmor radii) of ions (ρ_{hi}) and electrons (ρ_{he}). It can be seen from the Table, that ρ_{hi} throughout the ionosphere is greater or much greater than the dimensions of a satellite or equipment borne by it (their linear dimensions are of the order of 10^2 cm and several cm, respectively); as for the radius ρ_{he}, it becomes comparable to these dimensions only at 6—10 thou. km. The existence of the ionosphere was predicted as long ago as 1878, and again in 1889, in order to explain the periodic variations in the geomagnetic field, but it was only in 1925 that this prediction was proved with the use of radio waves. For many years the radio methods predominated in experimental exploration of the ionosphere; in recent years various methods of investigating the ionosphere with the help of satellites and rockets have been used. These methods essentially widened and deepened the studies of the properties and structure of the ionosphere.

IONOSPHERE SOUNDING with rockets. The methods of exploring the ionosphere with the use of rockets and satellites are arbitrarily divided into direct and indirect ones. The direct methods are used to determine electron and ion densities, temperature, composition, and plasma frequencies of the ionosphere, etc. The indirect methods of determining parameters of the ionosphere are based on its effect on some processes: wave propagation, deceleration of a satellite, etc.

The direct methods include: Langmuir probes of various design (so-called charged-particle traps for determining local densities and temperatures of electrons and ions); mass-spectrometers for determining the composition and mass of ions, as well as ion temperature; impedance probes for determining electron densities near the rocket or satellite by the change in resis-

tance of an electrically short antenna immersed into ionized plasma; measurement of plasma frequency to determine the local electron density.

The indirect methods include: sounding of the ionosphere (see IONOSONDE); the method of radio rising and radio setting of a satellite when determining the average dependence $N(Z)$ (see IONOSPHERE); measurements at coherent frequencies (DOPPLER EFFECT) of difference of Doppler frequency shifts (determination of local and overall electron densities); rotational Doppler effect due to the so-called Faraday effect, i.e., the interference of ordinary and extraordinary waves, when the overall electron density is primarily determined; radar or optical observation of an artificial cloud of increased ionization, produced by ejecting some easily ionized or luminous gases from a rocket (measurement of the directions and speeds of wind, atmospheric density, temperature, etc.); analysis of the spectrum of atmospheric whistlers and low-frequency atmospheric radiation; measurement of the amplitude and phase of the field of ground-based long-wave transmitters (determination of the collision rate in the D region).

IONOSPHERIC REFLECTION OF RADIO WAVES. Reflection of radio waves from the ionosphere caused by the change in the direction of their propagation due to a different height distribution of the index of refraction. The radio waves falling vertically are reflected in the regions of the ionosphere where the index of refraction becomes equal to zero; when the incidence is inclined, the reflection occurs in regions where refraction initiates a horizontal travel of the wave-front. Under specific conditions, a wide band of radio waves can be reflected from the ionosphere, ranging from long waves (5—10 km) to the upper ultra-short-wave boundary (10—15 m, even 6 m).

Long-range radio communication between two ground stations and, also, between an Earth satellite and a ground station can be maintained by repeated reflection of short waves from the ionosphere and the ground. Radio waves covering very long distances may follow a great variety of trajectories, they may be reflected from different regions of the ionosphere (E, F_1, F_2) and even from heterogeneous ionospheric formations that are liable to cause considerable deflection of the wave trajectory. The intensity of the radio waves has been found to increase in the vicinity of an antipode point located at a distance of about 20 thou.km (one half the Earth's circumference) from the transmitting station. This has been named the antipode effect and is due to the convergence of radio waves travelling along different trajectories at the antipode point.

ION ROCKET ENGINE. See ELECTROSTATIC ROCKET ENGINE.

ISOLATION (in space flight). Space flight is characterized by the absence of customary living conditions. The laboratory simulation of space flight has shown that isolation is a complex and peculiar irritant which, if applied for a long time, causes changes in the higher nervous activity, as well as in the somal and vegetative functions of the organism. With some individuals isolation may result in CLAUSTROPHOBIA. Selection of a group crew to man the spaceship apparently disposes of this problem, though a new one arises, *viz.*, the interrelated and interdependent activity of crew members under the unusual conditions of a prolonged space flight (see SPACE PSYCHOLOGY).

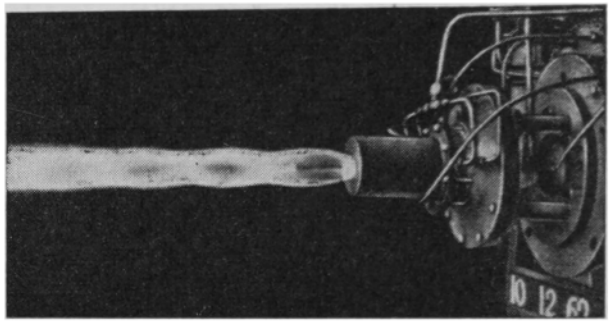
ISOLATION CHAMBER. A "silence" room with soundproof walls for checking the spaceman's reaction to total isolation and SENSORY DEPRIVATION. Is of great importance in training and selection of spacemen.

ISOTOPE ENGINE. See RADIO-ISOTOPE ROCKET ENGINE.

ITALIAN EARTH SATELLITES. The first Italian-made Earth satellite, the *San Marco-1*, was put into orbit on December 15, 1964. *San Marco-2* was launched on April 26, 1967, from a *San Marco* floating platform in the vicinity of the Equator. An American *Scout* launch vehicle was employed. Their orbits had apogees up to ~850 km and a perigee of ~200 km. The satellites are designed to study atmospheric density by aerodynamic deceleration and to investigate the properties of the ionosphere by measuring the propagation of radio signals at a frequency of 20.005 Mc/s. The spherical body of the satellite is 0.66 m in dia and it weighs 115—130 kg; no in-flight orientation is provided; energy is supplied from chemical sources (mercury batteries).

J

JET EFFLUX. The stream of the working fluid (gases, etc.), flowing from a rocket engine and creating the force of reaction. The formation of the jet efflux is the concluding stage of a rocket engine's working process.



Jet efflux of an operating liquid-propellant rocket engine.

JET ENGINE. A reaction engine which uses atmospheric air for burning the fuel. This engine is the backbone of jet aviation. In space flight it can be used for propelling aerospace planes, etc.

JET NOZZLE. See Nozzle.

JET PUMP. A device for ejecting a fluid at a high velocity, this inducing fluid having a lower pressure than the induced fluid, which causes a motion of the latter. It is used in liquid-propellant engines as an auxiliary jet propellant pump, or in static tests of rocket engines for building up a vacuum (in order to simulate high-altitude environment) at the nozzle outlet due to the inducing action of the gas jet of the rocket engine. More than once was it suggested to increase the thrust of rocket engines in the atmosphere by using jet pumps for inducing air by the gas jet of the rocket engine. The application of the jet pumps for feeding liquid propellant into the thrust chamber of rocket engines was first suggestep by Tsiolkovsky in 1914.

JUPITER. The largest planet in the solar system, and the 5th in the order of distance from the Sun. The mean distance to Sun is 5.202 A.U. (778 million km), the orbital eccentricity 0.0484, the inclination of orbital plane to ecliptic 1°18.3′, sidereal revolution period 11.862 years, mean orbital velocity 13.1 km/s. Jupiter is yellower than the Sun, its albedo being 0.73. The surface of Jupiter is not visible and determination has been made of the figure produced by non-transparent atmospheric layers: the equatorial diameter is 140,720 km which is 11.04 (Earth =1), the compression 1 : 15, the mass $1.9 \cdot 10^{30}$ g which is 317.8 (Earth =1), the mean density 1.3 g/cm^3, the acceleration due to gravity at the equator (less the centrifugal force of 2.26 m/s^2) is 23.0 m/s^2 which is 2.35 (Earth =1), the 2nd cosmic velocity, 57.5 km/s. The period of rotation determined from observation of the atmospheric bands at the central meridian is 9 h 50 min 30 s, that of the polar zones slower by 5 min 11 s. A strong radio source which is probably on the solid surface indicates that the period of rotation is 9 h 55 min 30 s, an inclination of the equatorial plane to the orbital plane is 3°4′. The visible disc

of Jupiter is crossed by a series of dark bands parallel to the equator (cloud formations). Drifting longitudinally in the moderate latitudes is the great "Red Spot" with a diameter of 10—40 thou. km, it may consist of small-size crystals. The temperature of the outer layers of Jupiter in the sub-solar point is 131°K. Jupiter's atmosphere consists of hydrogen and helium, with admixtures (<1%) of methane and ammonia. It is possible that beneath a 50-km layer of clouds of crystal ammonia and ice there is a zone where ammonia precipitates in the form of rain and vapour onto the lower tier of clouds of ice and water. The radio emission of Jupiter on wavelengths longer than 5 cm is strengthened by the presence of 2 radial belts spreading over 3 radii in the equatorial plane. This indicates the presence of a magnetic field of 2—5 Gs. Jupiter has 12 known satellites, 4 of them being giants. The largest of these is Ganymede with a diameter of 5.6 thou. km (larger than Mercury). They can serve as natural space stations for investigating Jupiter. Moving in the libration points of the Jupiter orbit are asteroids (9 in front of the planet and 5 behind it).

K

KEPLER'S EQUATION. An equation relating the eccentric anomaly (see ANOMALY, ECCENTRIC) to the mean anomaly (see ANOMALY, MEAN): $E - e \sin E = M$, where e is the eccentricity, E is the eccentric anomaly, and M is the mean anomaly. As a rule, E is determined from Kepler's equation by the method of successive approximations.

KEPLER'S LAWS. The laws describing the UNDISTURBED MOTION of celestial bodies, and derived by Kepler at the beginning of the 17th century from observations, the most precise of which were obtained by Tycho Brahe, Kepler's teacher. There are three laws: (1) every planet moves in an ELLIPSE with the Sun at one focus; (2) the radius-vector of each planet passes over equal areas in equal intervals of time; (3) the squares of the periods of revolution of two planets about the Sun are proportional to the cubes of the semimajor axes of their orbits. The third law is not quite exact. Departures from the third law are extremely small for planets of the solar system. The accuracy of observations at Kepler's disposal could hardly have been sufficient to detect such slight deviations.

KEROSENE. A fuel widely used in liquid-propellant engines; a mixture of hydrocarbons obtained by cracking petroleum or by its distillation in the temperature range of 150—300°C. A transparent, yellowish, high-boiling liquid with a specific odour; density, 0.82—0.84 g/cm^3, m.p., below —60°C. Slightly toxic. Chemically stable, does not attack structural materials; traces of water, sulphides, and organic acids accelerate corrosion. Produces a smoky flame with non-volatile impurities that tend to form a scale. Is more effective than alcohols, but less so than unsymmetrical DIMETHYL HYDRAZINE. Used extensively with LOX, concentrated hydrogen peroxide, and nitric acid oxidizers. Kerosene is cheap, widely available, and easy to handle. It has extensive technical applications.

KHRUNOV, Yevgeni Vasilyevich (born 1933, Prudy village, Volovsky District, Tula Region). Pilot-cosmonaut of the USSR. Hero of the Soviet Union. Member of the CPSU since 1959. Graduated from incomplete secondary (7-year) school, an agricultural technical training school, and a school for pilots. Served in Soviet Air Force since 1959; joined the group of cosmonauts in 1960. Graduated from correspondence department of the Zhukovsky Air Force Engineering Academy in 1968. On January 15—17, 1969, made a space flight as research engineer, leaving the Earth on board the *Soyuz-5* spaceship piloted by the cosmonaut B. V. Volynov. On January 16, Khrunov and the cosmonaut A. S. Yeliseyev walked through open space into the *Soyuz-4* spaceship piloted by the cosmonaut V. A. Shatalov and returned to the Earth in it. Khrunov orbited the Earth 32 times, covering a distance of 1,300,000 km in 47 h 39 min, including 1 h in open space.

KIBALCHICH, Nikolai Ivanovich (1853—81). A member of the *Narodnaya Volya* revolutionary group, author of the world's first design of a manned rocket. It envisaged a powder rocket engine, flight control by gimballing the engine, programmed burning of propellant, stabilization of the rocket, and other features. In 1871—75 Kibalchich was a student of the Institute of Railway Engineers and of the Medico-Surgical Academy in St. Petersburg. He was arrested in 1875 for possession of revolutionary literature, and

imprisoned for almost 3 years. In 1878 he took up illegal residence and headed the laboratory of explosives of the *Narodnaya Volya* executive committee. It was only during imprisonment in St. Petersburg prior to his execution that this talented inventor who devoted his entire life to the struggle against tsarism could formulate his scientific and engineering ideas. A crater on the far side of the Moon has been named in his honour.

KLEIMENOV, Ivan Terentyevich (1898—1938). One of the leaders and organizers of research and development in rocket engineering in the USSR. Head of the Gas Dynamics Laboratory (1932—33), and of the Rocket Research Institute (1933—37). A crater on the far side of the Moon has been named in his honour.

KOMAROV, Vladimir Mikhailovich (1927—1967). Pilot-cosmonaut of the USSR, engineer-colonel. Twice Hero of the Soviet Union. Member of the Communist Party of the Soviet Union since 1952. Graduated from the Air Force Special Training School in Moscow in 1945, the Air Force School of Pilots in Bataisk in 1949, the Air Force Engineering Academy in Moscow in 1959. Together with K. P. Feoktistov and B. B. Yegorov he made a space flight in the 1st multi-seater *Voskhod* satellite-spaceship. V. M. Komarov piloted the satellite-spaceship placed in orbit on October 12, 1964, and orbited the Earth 16 times in 24 h covering about 700,000 km. Two-way radio communication was established with the spaceship. TV broadcasting was effected from the spaceship. V. M. Komarov perished on April 24, 1967, when landing the *Soyuz-1*, a new type of spaceship, after a 24-hour maiden flight on a circumterrestrial orbit.

KONDRATYUK, Yuri Vasilyevich (1897—1942). One of the pioneers in Soviet rocketry. In his work *Tyem, kto budet chitat' chtoby stroyit'* (*To Those Who Will Read in Order to Build*, 1919), he expanded the basic problems of space flight. In 1929 he published a theoretical essay *Zavoyevanie mezhplanetnykh prostranstv* (*The Conquest of Interplanetary Space*) which was a partial repetition and further development of the works by K. E. Tsiolkovsky. He solved a number of problems in rocket dynamics and rocket engineering in a new way.

Kondratyuk was unfamiliar with the studies of Tsiolkovsky, and applied an original method to derive the principal equations of rocket motion. His works deal with the following problems: the minimum-energy space flight trajectories; the theory of multistage rockets; intermediate interplanetary rocket refuelling bases in the form of satellites of planets; and landing of rockets with atmospheric drag. Kondratyuk suggested the use of certain metals, metalloids, and their hydrogen compounds (such as boron hydrates, or boranes) as rocket fuels. A crater on the far side of the Moon has been named in his honour.

KONSTANTINOV, Konstantin Ivanovich (1818—1871). Lieutenant-general of Russian army, engineer, researcher in mechanics and engineering, production and application of combat missiles. Graduate of Mikhailovskoye Artillery School (1836). Commanded St. Petersburg Rocket Establishment (1849), and St. Petersburg Rocket Works (beginning 1850). Lectured on powder missiles to artillery officers (1859—1861). Head of Nikolayev Rocket Works (beginning 1867).

Designed and studied the ballistic properties of powder missiles. Beginning 1847 he investigated and improved missiles and promoted their production. He worked out the scientific basis for combat rocketry. Konstantinov's missiles were the most advanced in the 19th century, their flight range was 4—5 km. He radically improved the methods of missile application in combat. Konstantinov wrote: "At any instant during the burning of rocket composition, the momentum imparted to the vehicle equals the momentum of the exhaust gases" (*Artilleria*, part II, 1857, p. 261). Independently of Konstantinov, Tsiolkovsky deduced this same equality and derived the basic equation of rocket dynamics from it. Konstantinov wrote many papers in various fields of engineering and invented a number of artillery instruments, such as an electro-ballistic instrument for measuring shell velocity, an instrument for measuring flight altitude of signal rockets, an optical range finder, a collapsible sight for high-angle and ricochet shooting, a rocket ballistic pendulum. His most important papers were published in the *Artilleriysky zhurnal*, 1845—65, and *Morskoy sbornik*, 1854—66. He was the author of the book *Boyevye rakety* (*Combat missiles*, 1857). His lectures on missiles, delivered at the Mikhailovskoye Artillery Academy in 1860, were published in Paris in 1861; Russian translation appeared in St. Petersburg in 1864 as *O boyevykh raketakh*.

KORDYLEWSKI CLOUDS. Clusters of meteorite dust gathered at the libration points of the Earth—Moon system. Discovered in 1959 by the Polish astronomer Kordylewski. According to the laws of celestial mechanics, regions of stable equilibrium occur at two points (libration points) which are the vertices of two equilateral triangles formed with the Earth and the Moon in the plane of the Moon's orbit. Under certain conditions,

particles of meteoric dust that come near the libration points acquire an approximately periodic motion. The clouds can be observed on clear nights as faint elongated spots (photographed by Kordylewski in 1961 and by US astronomers in 1964). Their density is believed to be 2—3 orders greater than that of the surrounding space. Modern sensors could probably record a spacecraft's passage through the Kordylewski clouds.

KOROLEV, Sergei Pavlovich (1906—1966). Soviet scientist, designer of rocket and space systems. Elected Corresponding Member of USSR Academy of Sciences in 1953 and Academician in 1958. Member of CPSU since 1953. Twice Hero of Socialist Labour. Lenin Prize laureate. Born in Zhitomir to a teacher's family. In 1922 finished a building trades school in Odessa. In 1927 went to work in the aircraft industry. In 1930 graduated from the Moscow Higher Technical School and the Moscow Flying School. Designed a number of glider planes. After reading K. E. Tsiolkovsky, became absorbed in the idea of creating a rocket craft. In October, 1931, Korolev met F. A. Tsander with whom he collaborated in the organization of the Moscow Group for Study of Reactive Motion; he became head of the Group in 1931. In 1932, he was one of the organizers, and later the head, of the Group for Study of Reactive Motion (GIRD) which created and launched the first Soviet liquid-propellant rocket *GIRD-09* in August, 1933. After merging GIRD and the Gas Dynamics Laboratory late in 1933 and founding the Rocket Research Institute, Korolev was appointed its deputy director for science, and in early 1934, the head of the rocket vehicle department. His paper *Raketnyi polyot v stratosfere* (*Rocket Flight in Stratosphere*) was published in 1934. He designed a number of rockets, including the *212* winged rocket flown in 1939 and the *РП-318* rocket glider which made its first flight piloted by V. P. Fyodorov in 1940. During World War II Korolev was assistant chief designer of engines (1942—46), and worked on the problem of equipping production models of combat planes with rocket boosters. Later, Korolev headed a large team that designed high-power rocket systems.

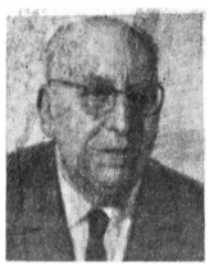
An era of outstanding firsts in the history of space exploration is associated with Korolev's name. For a number of years his high executive ability and scientific talent enabled him to direct the work of many research and design bodies solving stupenduous integrated problems. Many of Korolev's scientific and technical ideas have found application in Soviet rocket and space technology. He directed the development of many ballistic missiles, geophysical rockets, launch vehicles and the Vostok and Voskhod, the first spaceships in history used in man's space flights and space walks. Space rocket systems developed under Korolev ensured the launching of the world's first Earth and Sun satellites, flights of automatic stations to the Moon, Mars and Venus, and soft lunar landings. Developed under his dire-

ction were the ELECTRON, MOLNIYA-1, many of the COSMOS SATELLITES, and the ZOND series of interplanetary probes.

Korolev was the chief designer of rockets proper, space stations and ships. Other designers developed the rocket engines, flight control and other spaceborne systems, and the ground support equipment. It was the collaboration of their staffs and research institutes and factories that promoted the development of Soviet space science and technology. Korolev trained numerous scientists and engineers. In commemoration of the contribution made by Korolev as one of the founders of practical space flight, the biggest formation (a thalassoid) on the far side of the Moon has been named after him.

Korolev gold medal.

KOROLEV MEDAL. A gold desk medal instituted by the USSR Academy of Sciences in 1966; awarded for outstanding achievements in rocket engineering and space flight.



KRAMAROV. Grigory Moiseyevich (born 1887). Soviet writer. Member of CPSU since 1907. Author of articles and books on the history of Soviet rocketry. Chairman (1924) of Society for Studying Interplanetary Travel.

L

LANDING SYSTEM. A space-borne system of the re-entry body of a spaceship to ensure landing on Earth at a permissible speed and deceleration. This system usually comprises a parachute system, automatic controls for opening the parachutes at the prescribed altitude, mechanisms for the deployment of the parachutes and their detachment, means of spaceman's seat shock absorption, etc. In some cases the landing system will incorporate a retro-rocket to fully decelerate the re-entry body before touch-down (see SOFT LANDING).

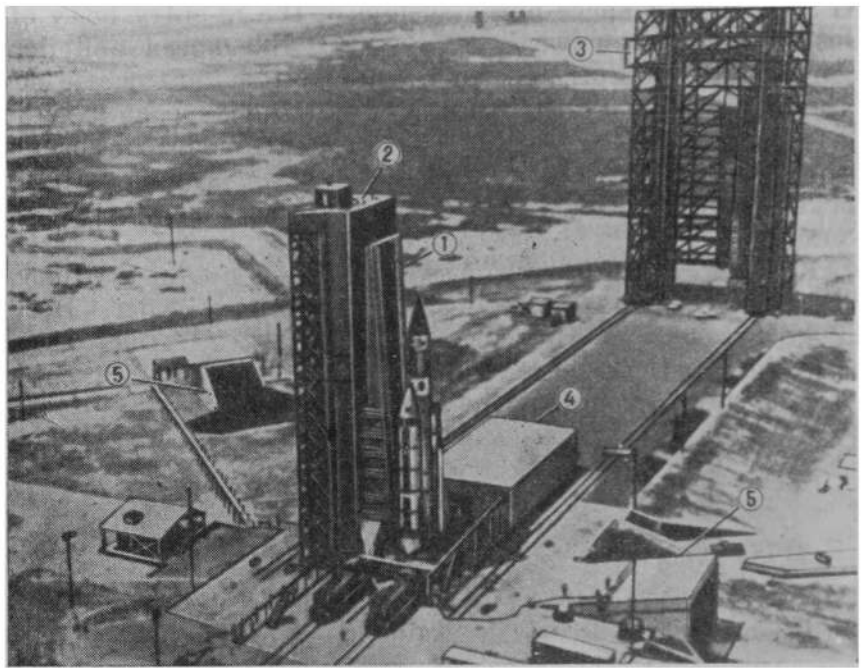
LANGEMAK, Georgi Erikhovich (1898—1938). A Soviet artillery engineer, designer of rockets firing smokeless long-burning powder. Between 1928 and 1933 he worked at the GAS DYNAMICS LABORATORY. Was one of the major leaders in the research work that later led to the development of the famous World War II *Katyusha* rocket mortar. In 1934—1937 he was Deputy Director and Chief Engineer of the ROCKET RESEARCH INSTITUTE. A crater on the far side of the Moon has been named after him.

LATERAL VELOCITY INDICATOR. A velocity indicator installed on the launch vehicle to measure lateral velocity, i.e., the velocity in a direction perpendicular to the plane of the design flight trajectory. In the simplest case, by means of the lateral velocity indicator the flight control system eliminates the lateral velocity of the launch vehicle and maintains motion strictly in a preset plane.

LAUNCH. Take-off of a space vehicle from the launcher; the series of operations and processes occurring within the "launch vehicle—launch complex" system after the operator has pressed the *fire* push-button on the launch control console. The major operations of launch include: pressurization of the launch vehicles propellant tanks; starting the control system instruments; starting the rocket engine and running it into the normal operating rate; the take-off of the launch vehicle from the launch pad and its exit from the zone of possible collision with the elements of the launcher. Launch is accompanied by an intensive impingement of the rocket efflux on the elements of the launcher and the arise of a powerful acoustic field.

LAUNCH COMPLEX. A complex comprising ground operating equipment, structures holding general-purpose technical equipment, and specially prepared plots of land with transport ways. This complex provides for the delivery of space vehicles from the MAINTENANCE AREA to the LAUNCHING PAD, its installation on the launcher, check-out, fuelling, alignment, and take-off. The launch complex may include several launching pads.

LAUNCH CONSOLE commands the operations directly preceding the launch. Execution of the orders is reported by an annunciator. When orders are given by the launch commander, the operator sets the firing key on *fire* and presses the *fire* button. All subsequent operations are automatic: closing of the pneumatic valves of the oxidizer and fuel tank drain lines; pres-



View of launching site (USA).

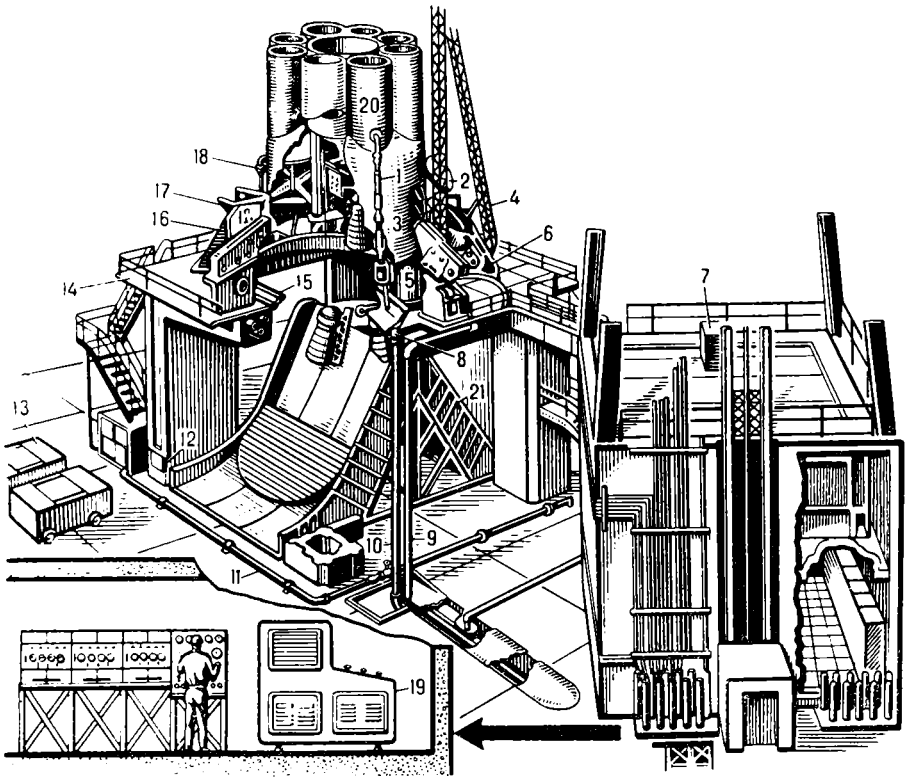
1—launcher upper part and cable mast; *2*—umbilical tower; *3*—service tower; *4*—shed for protecting check-out and launch equipment against jet impingement and acoustic load; *5*—exhaust-gas ducts.

surization of propellant tanks; starting of the launch vehicle powerplant; delivery of propellant components to the rocket engine; and thrust build-up. When the thrust exceeds the take-off weight, the space vehicle leaves the launching pad. After lift-off, the check-out and launching equipment is de-energized by pressing the *stop* button. The launch console is installed at the control centre of the launch complex. Launching can also be controlled from an outlying launch console.

LAUNCH CONTROL CENTRE. A hard or semihard structure of a launch complex, which accommodates the equipment for remote and automatic control of erection of launch vehicles on a launcher, their vertical alignment, loading the propellants and charging compressed gases. Arranged at the launch control centre is also the check-out and launch equipment. A launch vehicle can also be triggered from an outlying launch control centre, located at a considerable distance from the launcher, sometimes even in the MAINTENANCE AREA.

LAUNCHER. An arrangement designed for accepting, vertical alignment and holding of the launch vehicle in the firing attitude, bringing up electric, propellant-loading, drain and other lines, as well as for performing the launch proper. Some launchers are provided with equipment and machinery for azimuth alignment of the rocket. The main components of the launcher are as follows: support structure; launch vehicle support elements; devices and mechanisms for its vertical alignment; wind and storm anchoring devices;

accessories for connecting the launch vehicle to and disconnecting it from electric, pneumatic, filler, and drain connectors; a flame deflector and gas ducts; control and interlocking devices. The supporting structure of some launchers employs several hinged supports or trusses onto which the bottom or middle section of the launch vehicle is installed; at take-off these supports

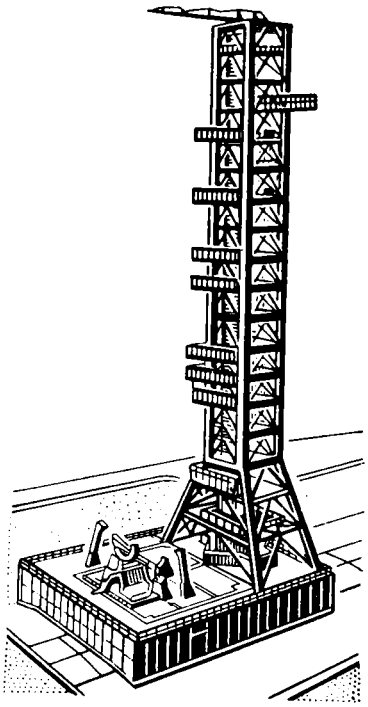


Rocket launcher (USA).

1, *18*—umbilical towers; *2*, *4*—cable masts; *3*, *7*—heaters; *5*, *16*—rocket supports; *6*—valves; *8*, *9*, *10*—fuelling pipes; *11*—water supply pipe; *12*—hydraulic system control panel; *13*—vans carrying engine servicing equipment; *14*, *19*—control panel of engine servicing system; *15*—electric cables; *17*—leakage detection panel; *20*—rocket tail; *21*—flame deflector.

(or trusses) are swung aside automatically in order to prevent their collision with the launch vehicle. In cases when the body of the launch vehicle is rotated for azimuth alignment, the supports are fixed to the rotating part of the launcher.

LAUNCHER IMMOBILIZATION. A set of operations carried out to lock the lifting mechanisms (if they have no self-braking devices) and rigidly secure the rotary section of the launcher. These operations are performed after azimuth and VERTICAL ALIGNMENTS of the launch vehicle and are intended to reliably fix the lifting and rotary elements of the launcher during launch, thus retaining the launch vehicle in established spatial orientation up to the moment of take-off. Launcher immobilization also prevents any unde-



Upper part of a launcher and the umbilical tower.

sirable rotation and displacement of its components due to jet impingement at launch. Immobilization is accomplished by means of different kinds of locking mechanisms, such as grips, clamps, brakes. These mechanisms are actuated, as a rule, by springs or manually and inactivated by remote or manually controlled electrical, pneumatic, or hydraulic devices. In case of failure in the electric, pneumatic, or hydraulic lines, the locking mechanisms automatically immobilize the launcher.

LAUNCHING PAD. The site from which launch vehicles are sent up; the launching structure accommodating a launcher and some of the launch complex equipment. Sometimes the launching pad is used for vertical assembly of launch vehicles after they have been prepared for assembly at the VEHICLE ASSEMBLY BUILDING, as well as for mating of spacecraft.

LAUNCHING TABLE. A movable launcher; its bearing structure is a frame mounted on 3 to 6 vertical supports or pillars spaced around the flame deflector. The supports may incorporate built-in lifting mechanisms that move the frame so that the launch vehicle can be received and vertically aligned. Such mechanisms may also be built into the framemounted support elements that hold the launch vehicle. Some tables have a rotary unit for azimuth alignment of the launch vehicle. In working position the table is fixed to the concrete foundation of the launch pad.

LAUNCH INTERLOCK. A set of devices that prevents a launch operation from beginning before the preceding scheduled operations have been completed. It guarantees the preset operating sequence of the launcher systems and rules out emergencies due to a garbled sequence in erection, filling and launching. For example, the erector arm grabs cannot release the launch vehicle until the latter has been secured in the launcher, and the erector arm cannot return to horizontal position until the grabs release the vehicle; in the tank filling process the charging valve of the fuelling line will not open until the pressure pick-up of the supply tank signals that the tank has been completely pressurized, and the fuel pump drive will not start until there is a signal indicating that the pump body has been primed.

LAUNCH STRUCTURE. The structure serving to accomodate the launcher, some of the check-out and testing equipment, certain components of the propellant-loading system, sources of electric power, and to bring the cable, propellant-loading and compressed air lines up to the launcher. The launch structure is made up of supporting columns, pillars, flame deflectors, gas ducts, etc. Ground, semi-buried and silo type launch structures are known.

LAUNCH VEHICLE. A multi-stage ballistic rocket intended for launching a payload into space, e.g., a vertical geophysical or space probe, an Earth satellite, an automatic interplanetary station, a spaceship, etc. The launch vehicle is a space rocket which usually has 2—4 stages and is used for accelerating the payload to a velocity equal to, or greater than, the 1st or 2nd cosmic velocity.

LEGAL STATUS OF CELESTIAL BODIES. A complex of international legal problems which arise in connection with activities of different states in exploration of the Moon and other celestial bodies. The legal status of the Moon and other celestial bodies shall be subject to standards and regulations of space law. The freedom of scientific exploration and use of the Moon and other celestial bodies should have its limits and restrictions to be established by the space law standards. Article IV of the 1967 AGREEMENT envisages a ban on the installation of nuclear weapons or any other means of mass annihilation on celestial bodies, as well as a ban on setting up military bases, structures, or fortifications there, testing any types of weapons and conducting military manoeuvres. The principle prohibiting national usurpation of celestial bodies is of great importance for the definition of their legal status. A state which sets up a research station or a settlement on the Moon or any other celestial body undoubtedly should, by virtue of its responsibility for everything that takes place there, exercise jurisdiction with respect to its citizens or subjects at the station or in the settlement, and also with respect to all events taking place there. It is in this that state sovereignty will manifest itself. This, however, will not mean the extension of state sovereignty to the celestial body as a whole, which would be equivalent to its national usurpation. In Western literature dealing with the legal status of the Moon and other celestial bodies, one can often find arguments in favour of placing them under control of the United Nations or some other international organization. Experience on Earth, however, does not support such proposals.

LENINGRAD GROUP FOR STUDY OF REACTIVE MOTION (LenGIRD). A public body set up in Leningrad in November 1931, under the auspices of the Bureau of Aeronautics of the Regional Council of the *Osoaviakhim* (Society for Assisting Defence and Aviation and Chemical Construction in the USSR), with the aim of combining the efforts of rocketry enthusiasts. Among the organizers and active members of LenGIRD were Y. I. PERELMAN, N. A. RYNIN, and V. V. RAZUMOV (first chairman of the Group), the engineers A. N. Stern and Y. Y. Chertovskoy, the physicists M. V. Gazhala, I. N. Samarin, and M. V. Machinsky and several public figures. The Group was rendered assistance during its establishment and in organization of its work by B. S. PETROPAVLOVSKY, V. A. Artemyev and other staff members of the Gas Dynamics Laboratory. LenGIRD actively disseminated knowledge on rocketry, organized a number of demonstration launchings of small powder rockets, and developed several original experimental rockets (photo rocket, meteorological rocket, etc.), including the Razumov-Stern rocket with rotary liquid-propellant engine. In the autumn 1932, the Group set up a course in the theory of reactive motion. In 1934 LenGIRD was transformed into a Reactive Motion Section which, under M. V. Machinsky's direction, continued dissemination of knowledge, investigated the effect of acceleration

on animals, and up to the beginning of the World War II continued to develop and test new models of liquid-propellant engines and rockets of novel design.

LEONOV, Alexei Arkhipovich (born 1934, Listvyanka village, Kemerovo Region). Pilot-cosmonaut of the USSR, colonel, Hero of the Soviet Union. Member of the CPSU since 1957. In 1953, in response to an appeal of the Young Communist League, he entered a flying school. After graduating from the Chuguyev Air Force School, he served in various units of the Air Force. In 1960 was given the rank of Air Force paratroop instructor. Graduated from the Air Force Engineering Academy in Moscow in 1968. On March 18, 1965, together with P. I. Belyayev made a space flight in the *Voskhod-2* spaceship as co-pilot. During this flight, for the first time in history, Leonov stepped out into open space, moved up to 5 m away from the spaceship and spent 12 min in open space.

LEVEL GAUGE. An instrument used for measuring and recording the level of a liquid in a tank. The instrument consists of the level gauge proper and a secondary indicator. The level of the liquid is recorded either continuously or discretely. The method of discrete measurement permits recording of only certain levels, whereas with continuous measurement the level can be determined at any moment. Induction, capacitance, optical, acoustic, and ultrasonic level gauges are in general use. The level gauges installed in the tanks of the launch vehicle and the propellant terminal make it possible to determine the amount of propellant supplied to or discharged from the tank.

LIABILITY FOR DAMAGE (in space law). The international liability for damage caused by space objects on the Earth, in the air or in outer space. It is governed by Article VII of the 1967 Agreement. In conformance with this article, all states, party to the Agreement, that launch a space object or allot their territory or equipment for launching such objects, are liable to international responsibility for damage caused by such objects or by their component elements to any other party to the Agreement or to its legal body or person.

LIFE OUTSIDE EARTH. See Exobiology.

LIFE SUPPORT SYSTEM in space flight. Characteristics of circumterrestrial space and many celestial bodies are extremely low pressure and a different gas composition of the atmosphere (absence of oxygen necessary for respiration of living organisms), sharp fluctuations of temperature on the surface of celestial bodies and in their gas shells, various types of radiations (including cosmic and short-wave UV-radiation, which are extremely dangerous to living organisms), and the action of solid interplanetary matter, i.e., meteors. Hence, man's penetration into space, and his existence there are possible only if appropriate protection is provided. Protection against adverse factors of space flight is ensured by spaceship sealed cabins and/or individual space suits. The conditions necessary for life and activity of man are created and maintained in the limited space of sealed cabins by a LSS. This system maintains an artificial gas environment (air) with optimum physical parameters (pressure, temperature, humidity, speed of motion, etc.) and chemical composition; it provides the crew with oxygen, food, and water and removes human and other biological wastes (see Biocomplex).

Design and arrangement of the elements and units of the LSS depends to a large extent on the duration of the space flight. The amount of compensa-

tion for basic materials and elements consumed during metabolic processes in the small closed volumes, determines whether the type of LSS used is open, semi-closed or closed circuit. Open systems contain stocks of oxygen, food and water; solid and liquid biological wastes are collected in special containers, while gaseous products are absorbed by filters. Semi-closed LSS have installations for water regeneration and production of oxygen by electrolysis of water or by decomposition of carbon dioxide; all other details are the same as in open systems. Closed-circuit LSS are based on circulation of main elements and materials within small confined volumes of spaceship, with on-board reproduction of food products, oxygen and water regeneration by PHOTOSYNTHESIS and water electrolysis and utilization of human and other biological wastes. All life support systems may be subdivided into systems using physico-chemical methods for regeneration of materials and elements, and systems based on biological circulation of materials. The latter systems are not always expedient for small confined volumes, therefore some units and elements of these systems employ physico-chemical methods of regeneration and utilization.

A standard LSS should include sub-systems for creation and maintenance of a standard gaseous environment in the sealed cabin, food supply, water supply, and sanitation. The sub-system that creates and maintains a standard gaseous environment (air) should keep up the prescribed artificial atmosphere in the spaceship cabin throughout the entire flight or expedition to another celestial body; the oxygen consumed by man and other biological objects must be compensated for, and excess carbon dioxide and noxious contaminations removed. In short-time space flights, oxygen is catered from supply taken on board in gaseous form in pressure cylinders, or in the liquid state in Dewar flasks (oxygen tanks or gasifiers), or else in the form of chemically active compounds of oxygen and alkali or alkaline-earth metals. Such chemical sources of oxygen were used in the Soviet VOSTOK and VOSKHOD spaceships and in the American MERCURY and GEMINI spaceships. Carbon dioxide may be removed from the cabin atmosphere by filters, or alkalis of certain metals. In space flights of medium duration, oxygen may be obtained by electrolysis of water or solution of salts, or by decomposition of carbon dioxide. The latter may be removed from the cabin atmosphere with the use of zeolites or by its utilization. In extended space flights the same methods are used as in medium-duration flights, or use is made of vegetable organisms (higher and lower AUTOTROPHS) which liberate oxygen as a result of photosynthesis; the reaction of photosynthesis takes place in light with assimilation of carbon dioxide from the cabin atmosphere.

In short- and medium-duration space flights, the sub-system providing food consists of stocks of prepared natural or freeze-dried (see FREEZE DRYING) food products. In extended flights on orbiting stations or expeditions to other celestial bodies, the main function of this sub-system should be the production of food on board the spaceship; the vegetable food in this case will consist of the biomass of plants that serve for regeneration of oxygen in the photosynthetic reactors (gas exchangers) of the LSS. In spaceships intended for extended space flight, there will be a surplus of biomass that can be expediently used as food for animals and microorganisms (HETEROTROPHIC

ORGANISMS). These, in turn, are a good source of animal proteins which are of vital importance for man.

The water supply sub-system in short space flights is the stock of water taken on board. In medium-duration and, moreover, extended space flights, the water supply must be based on small stocks of water with mandatory water regeneration from human wastes, TRANSPIRATION MOISTURE and ATMOSPHERIC MOISTURE CONDENSATE.

The sanitation sub-system consists of washing facilities, waste management and food waste units. In short- and, possibly, medium-duration space flights the materials used in this sub-system and human wastes will be deodorized, disinfected and stocked in special containers. In extended space flights all the materials of this sub-system must be utilized; the utilization of human and other biological wastes is possible only after their mineralization. Therefore, in extended space flights and especially, in expeditions to other celestial bodies and in orbital research laboratories functioning of the LSS should be based on circulation of materials in a small confined volume; this is sometimes called an ECOLOGICAL SYSTEM, with oxygen, water and food balance. The rational degree to which an LSS is closed is determined by the flight duration. However, in practically closed LSS based on circulation of materials certain stocks of the latter (critical masses of initial substances) are required. The weight and size of open or semi-closed LSS depend on the duration of the flight.

Each sub-system or link of an LSS, including the sub-system for physicochemical regeneration, or an individual biological link (man included) is an open-circuit system. The principal condition for its normal functioning is a continuous input of the necessary initial substances and energy, and output of the end products. To achieve this, attempts are made to combine the open sub-systems into a closed-circuit functional chain of substance recovery. In such a circuit the output characteristics of the preceding subsystem should correspond to the input characteristics of the following subsystem (if there is no correspondence, special coordinating elements are introduced). A closed-circuit LSS based on material circulation can be designed, that ensures long-term self-contained existence without additional supply of materials from outside. The main advantage of this type of LSS is the possibility to repeatedly use the initially limited stock of materials. Circulating the materials in order to provide for man's existence creates a novel, not previously experienced situation in which the LSS is directly dependent on man as one of its components and main links. This dependence is so great, that the conventional meaning of the notion "life support system" becomes relative with respect to man, since he is the object supported to the extent to which he himself supports normal functioning of the other subsystems of the biotechnical system. The inclusion of man in the LSS as one of its functional sub-systems is the only rational method of ensuring the vital activity of the crew in extended space flights.

The circuit of an LSS may be closed only for some of the materials (oxygen, water) and remain open for others. The greater the number of materials recycled within the system, the nearer it is to a closed-circuit system. The prototype of the latter system is the circulation of materials in the terre-

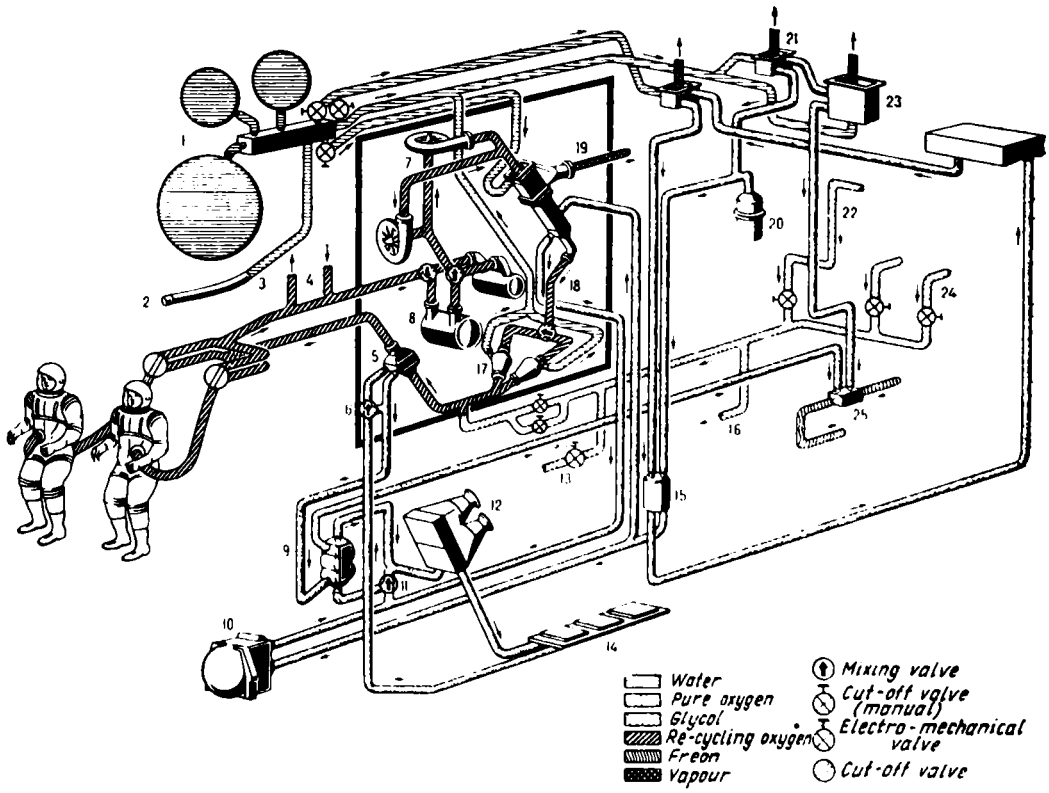
strial biosphere. However, it cannot be transferred to a sealed cabin, since this circulation involves a tremendous number of links and various materials; the exchange processes in it are very slow and are separated in time and space. Geochemical processes also participate in the terrestrial circulation.

Normal functioning of closed-circuit LSS based on recycling of materials depends on the optimum circulation rates of each material. The better the balance of rate of material circulation in individual subsystems and in the LSS as a whole, the greater the equilibrium and, consequently, the stability and reliability of the system. The study of energy and material transformations in the biotechnical system and in its individual sub-systems, man included, is a task of cardinal importance and complexity, since the object of study is a closed-circuit biotechnical system intended for long-term self-contained existence in an enclosed space. Alongside its theoretical significance, this problem is of vast practical importance, since the purpose of this system is to enable man to live outside the Earth's biosphere without material connection with the environment. The principal requirements for determining the structure of a LSS and of its individual elements are: equilibrated functioning of the system to provide man with all necessary products; coordinated rate of material and energy exchange between individual sub-systems with minimum dispersion (losses) of each element and minimum occurrence of material impasses; biological compatibility of all the elements of the system, the micro-organisms being used as intermediaries; stability (reliability) of the system in cases of diverse fluctuations that unavoidably arise in a complicated and multi-component system, as well as resistance of individual biological links, and the system as a whole, to unfavourable effects produced by specific conditions of space flight.

On the basis of preliminary estimation of man's requirements of food, water and oxygen, and evaluation of possible ways of meeting these demands in the conditions of extended space flights it is assumed that the biotechnical system will be constituted of man; plants, animals; food supply sub-system; waste utilization sub-system with chemical correction of nutrient solutions for plants and animals; physico-chemical correction sub-system; and water-regeneration sub-system (7-unit LSS). Since in the terrestrial biosphere there is only one known way of reproducing organic food substances from inorganic materials, that employing plants (autotrophs), it is probable that precisely this unit will be a constituent of the system. This method of reproduction of provisions is the most practicable and, in fact, the only possible means of obtaining nutritionally complete food products during flight. Beside food products, plants produce oxygen and water, ensure utilization of CO_2 and biological wastes: if farmed correctly, plants make it possible to obtain food products throughout the flight. At the same time they create an environment customary for man, which is psychologically valuable. However, the autotrophs cannot provide man with a sufficient amount of animal proteins and saturated fatty acids (animal fats); for this reason a heterotrophic link (animals) is necessary in the LSS. The latter, however, complicates the functioning of the utilization and physico-chemical correction links, and somewhat reduces the efficiency of the system as a whole. The utilization link should include units for physico-chemical mineralization of all solid, liquid, and

gaseous biological wastes of man, autotrophs, and heterotrophs, and a unit for preparation of NUTRIENT SOLUTIONS for plants and animals with chemical correction of these solutions. The food link is necessary to increase the nutritive value of food products obtained from plants and animals, and also for culinary and technological processing of food products to prepare food palatable to man. The purpose of the sub-system for physico-chemical correction is to replenish possible deficiency of oxygen, to remove noxious contaminants from the air, to maintain design moisture and temperature levels, and to create conditions necessary to withstand certain emergency situations. The mission and the route of a particular flight will determine how the biotechnical system used is modified, e.g., animals may be excluded and the stocks of certain products increased, etc.

LIFE SUPPORT SYSTEM OF APOLLO SPACESHIP. This system is rated for a 14-day flight of 3 astronauts in the Command Module (orbital spaceship) and a 48-hour stay of 2 astronauts in the Lunar Excursion Module (landing spaceship). The cabin atmosphere: medical-grade oxygen at a pressure of 0.35



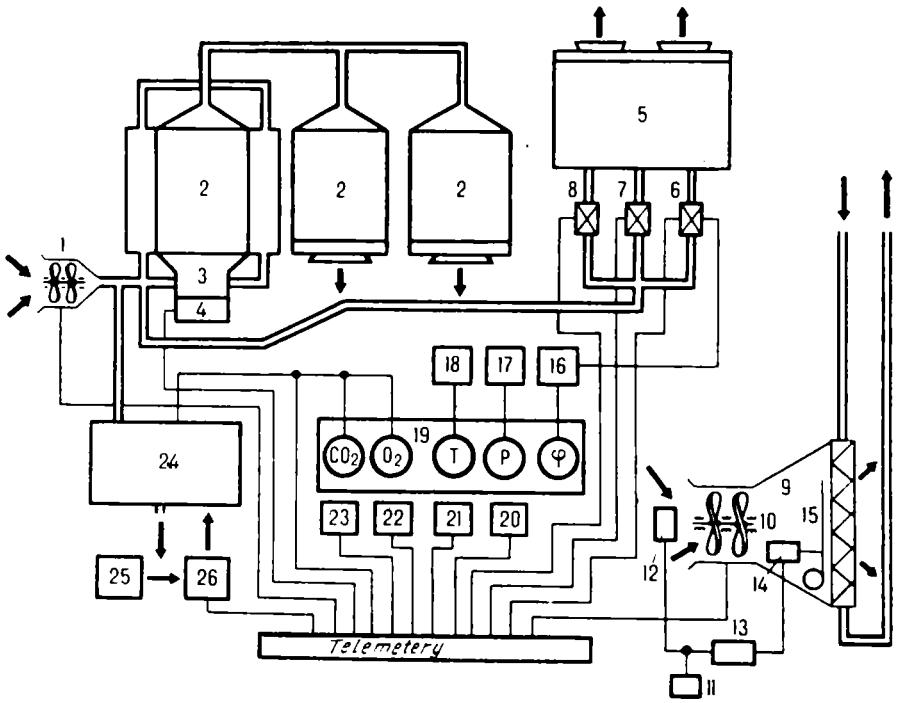
Schematic diagram of LSS of *Apollo* Lunar Excursion Module.

1—water tanks; *9*—sleeve for charging water into self-contained life support system of space suit; *3*—cabin oxygen inlet; *4*—cabin oxygen outlet; *5*, *18*—oxygen-glycol heat exchanger; *6*—temperature control unit; *7*—space suit fans; *8*—lithium hydroxide and contaminant absorbers; *9*—glycol-glycol heat exchanger; *10*—radio-electronic equipment; *11*—cabin temperature control system; *12*—cabin heat exchanger and fans; *13*—emergency cabin pressurization valve; *14*—cooling plates; *15*—glycol pumping unit; *16*—sleeve for charging oxygen into self-contained life support system of space suit; *17*—moisture separators; *19*—ice sublimator; *20*—glycol accumulator; *21*—water evaporator; *22*—low-pressure oxygen; *23*—glycol evaporator; *24*—high-pressure oxygen; *25*—freon evaporator.

at ab supplied from a GASIFIER, where LOX is stored at a supercritical pressure. Carbon dioxide is absorbed by LITHIUM HYDROXIDE placed in cartridges. Freeze-dried food products in special packages are stored in a container. The crew's biological waste is collected in containers with preservatives. Temperature in the command module is controlled by cooling the oxygen with an intermediate coolant in a radiation-type heat exchanger or, during peak emissions of heat, in a glycol evaporator. The temperature control of the Lunar Excursion Module is achieved by cooling the oxygen in water and glycol evaporators. In the Command Module moisture condensed in the space suit heat exchangers is pumped by a pneumatically-driven pump into a storage container, in the Lunar Excursion Module it is removed by two centrifugal moisture separators. The LSS of the Lunar Excursion Module consists of 54 units with a total weight of 103 kg. Power consumption is 251 W.

LIFE SUPPORT SYSTEM OF SPACESHIP, control of. The control of the LSS has been provided to create an optimum life environment for members of the crew and the biocomplex, and the conditions necessary for efficient operation of each sub-system and link of the LSS and the system as a whole. In LSS based on space-borne supplies taken from Earth, it is necessary to control the BIOLOGICAL AIR REGENERATION and conditioning systems; in physico-chemical systems based on utilization of human biological wastes, there must be a control of the rate of biological air regeneration, and of waste decontamination and utilization, as well as maintenance of optimum air temperature in the spaceship sealed cabin. In LSS based on biological recycling, control of such elements as light intensity and dosing of nutrient media is of great importance.

LIFE SUPPORT SYSTEM OF VOSTOK SPACESHIP. The air regeneration and conditioning were effected in the LSS of the *Vostok* spaceship by a unit, which comprised a regeneration device, an air cooling and desiccating device, moisture absorbers, and monitoring and control devices. The source of oxygen was an alkali metal superoxide capable of liberating oxygen and absorbing carbon dioxide when the humid air of the cabin is blown above it. At the outlet of the regeneration device a filter was mounted to absorb noxious contaminants from the air. The air was desiccated by absorption of part of the moisture by the oxygen regenerant, by precipitation of air moisture on the cooled surfaces of the heat exchanger of the cooling and desiccation unit, and by absorption of moisture by chemical absorbers on a base of impregnated fabric. The required temperature and humidity in the cabin were maintained by the cooling and desiccation unit that comprised a heat exchanger, a vibrator, a temperature control, etc. The heat from the cooling and desiccation device was abstracted by a coolant supplied from the temperature control system. The whole of the food and water stocks were packed in containers in aluminium tubes and plastic film packages. Solid and liquid human wastes were removed via a SANITATION UNIT. The atmospheric conditions in the spaceship cabin were: pressure, 755—775 mm Hg; oxygen content, 21—25% by volume; carbon dioxide content, 0.35—0.5% by volume; relative humidity, 51—57%, air temperature, +13 to +26°C. (See Fig., p. 224).



Air regeneration and conditioning on *Vostok* spaceship.

1, *10* — electrically-driven fan; *2*, *3*, *4*—adjustable regulators, dust filter and contaminant filter; *5*—moisture absorber unit; *6*—automatic valve; *7*, *8*—manually operated valves; *9*—air-liquid heat-exchanger with condensed moisture collector; *11*, *12*, *13*, *14*, *15*—automatic temperature regulators (controller, pick-up, amplifier, actuator, and adjustable screen); *16*, *20*, *21*—humidity gauges; *17*, *23*—pressure gauges; *18*, *22*—temperature gauges; *19*—control console; *24*, *25*, *26*—automatic gas analyzers measuring oxygen and CO_2 content.

LIFT/DRAG RATIO. The ratio of lift force to the drag force of an aircraft or a spacecraft. The external lines of spacecraft designed for rigorous re-entry conditions is far from being aerodynamically perfect; therefore, their lift/drag ratio is about 0.5 or less. Low lift/drag ratio of re-entry bodies is made up by high flight velocity which develops a lift sufficient for effective flight control.

LIFT FORCE. An aerodynamic force that acts on a spacecraft descending into an atmosphere. It is directed perpendicular to the flight trajectory. At a roll angle of 0°, the lift force is exerted in an upward direction and reduces the descent speed, whereas at an angle of 180° it is directed towards the surface of the planet and increases the speed of descending or, if the speed exceeds the orbital value, the lift force prevents the spacecraft from moving away from the surface of the planet and tends to keep it within the atmosphere. The direction of the lift force can be varied by controlling the roll angle of the descending spacecraft, this being one of the methods for CONTROLLED RE-ENTRY into an atmosphere.

LIFTING MECHANISM. The mechanism of a launcher, intended for lifting and lowering the supports on which space vehicles are installed; by moving these supports, vertical alignment, lifting or lowering of the space vehicle

is achieved, and the supports are brought in contact with the space vehicle when the latter is being erected on the launcher. The lifting mechanisms may number 3, 4, 6, 8 and more, depending mainly upon the design of the space vehicle support structure. The lifting mechanisms are subdivided into mechanical (screw jacks) and hydraulic (hydraulic jacks, hydromechanical supports). The lifting mechanisms are set in operation by a manual (supplementary), motor, or selsyn drive, the latter being employed on launchers with automatic systems of vertical alignment of the space vehicle.

LIGHT YEAR. See ASTRONOMICAL UNIT.

LINCOS. An artificial language developed by the Dutch mathematician H. Freudenthal in 1960 and meant for communicating with inhabitants of other worlds (see EXTRATERRESTRIAL CIVILIZATIONS). As different from the artificial languages of mathematical logics or computer languages Lincos cannot and does not have a metalanguage, i.e., one telling about the new language. Teaching of Lincos is similar to a child's learning of his native tongue which begins from a "blank" with the added difference that the possibilities for using illustration as a teaching method are reduced to a minimum. Lincos is a moderately formalized language occupying an intermediate position between completely formalized and natural languages. The addressee to be communicated with in Lincos is presumed to have reached at least the same level of development as the inhabitants of the Earth and possess a system of general notions similar to ours. The physical basis of the signals does not matter for constructing Lincos. Such basis could be radio signals of different frequency and duration, a definite combination of these parameters corresponding to each character of the language. Each character corresponds to a certain notion. Teaching Lincos takes the form of a strict succession of lessons-transmissions, the object of which is gradual introduction of new characters in the context of the known ones, their consolidation, definition of the laws of the language and their explanation by examples, and lastly, communication of facts. Widely employed is the method of pseudo-general definitions when instead of strict definition a large series (hundreds, thousands) of examples are given in which the addressee should detect some common feature, i.e., the concept being defined. Teaching starts with mathematical concepts, most likely to be common among inhabitants of different worlds. By means of natural numerals (presented as a series of simple dot signals) such signs are introduced, as $>$, $<$, $=$, $+$, $-$, and the notion of the scale of notation (binary). After that the main concepts of mathematics are presented step by step, up to elements of analysis, time and space concepts are established, and thus a grid is plotted for describing objects and events. On this basis it is already possible to communicate rather complex facts and concepts, including social and ethical ones. The construction of Lincos has not yet been completed, but in principle, by gradually developing its ideas, it is possible to describe in Lincos any human concept, however, complex. So far Lincos is the only language of this kind, but theoretically other similar languages can be constructed as well.

LINEAR ACCELERATION INTEGRATOR. An instrument used for determining the APPARENT VELOCITY of spacecraft. The operation of linear acceleration integrators is based on the employment of a sensor (e.g., a calibra-

ted weight or pendulum) that records the APPARENT ACCELERATION; the apparent speed is determined by integrating the values of the apparent acceleration. This is achieved by utilizing the phenomenon of gyroscope precession, (see GYROSCOPIC INTEGRATOR) by electrolysis and by other means. The linear acceleration integrator and the accelerometer, are the basic types of sensing elements used in inertial systems of spacecraft control.

LINE OF APSIDES. The line that passes through the centre and pericentre of an orbit. In the case of an elliptical orbit it is the line connecting the PERICENTRE with the APOCENTRE.

LINE OF NODES. The straight line of intersection of an orbital plane with the fundamental plane (see ORBITAL ELEMENTS). In the theory of planetary motion, the line of nodes is the line of intersection of the orbital plane of the planet with the plane of the ecliptic. In the theory of motion of Earth satellites, the line of nodes is the line of intersection of the orbital plane of the satellite with the plane of the Earth's equator.

LIQUID DETECTOR. A transducer that operates on being immersed in a liquid. Liquid detectors are employed for detecting gas bubbles in engine propellant-feed pipelines, or when filling the propellant pipelines of the propellant-loading system before fuelling the launch vehicle tanks. This detector has a normally open contact that is closed by the conducting propellant. In the case of non-conducting propellants, use is made of a capacitance method of indication based on the difference between the dielectric constant of the vapour and liquid phases. The detector is an element of the system of remote-control of fuelling and the system of fuelling operations interlock.

LIQUID PROPELLANT. A substance or a combination of substances capable, as a result of the chemical reactions of oxidation, decomposition, or recombination, of releasing heat energy carried by the reaction products and used in rocket engines as the working substance. The liquid propellants chiefly used are those that generate energy due to the reaction between an OXIDIZER and a fuel. There are also SINGLE-COMPONENT MONOPROPELLANTS, i.e. chemical compounds releasing chemical energy in the combustion chamber of a rocket engine, and MONOPROPELLANTS, i.e. solutions of a fuel in an oxidizer. Liquid-propellant engines in use today are based on BIPROPELLANTS with the oxidizer and fuel separately stored and fed into the engine, which is safer in operation, and the components of the propellant can be chosen from a wide variety of substances. MULTIPROPELLANTS are under study, including TRIPROPELLANTS capable of producing a maximum SPECIFIC IMPULSE. Monopropellants releasing energy on decomposition, e.g., HYDROGEN PEROXIDE or HYDRAZINE, have been put to use in rocket technology. According to a characteristic which is of importance for operation, i.e. the temperature range in which they retain the liquid state, liquid propellants are classified as cryogenic, low-boiling, and high-boiling. Liquid rocket propellants that are physically and chemically stable in operational environment are referred to as storable. Liquid propellants can contain solid admixtures that increase their effectiveness, namely the specific impulse and density (see SUSPENSIONS, QUASILIQUID

PROPELLANT); their gaseous combustion products can contain the condensed phase. The following are the principal requirements for liquid propellants: production of a preset specific impulse; sufficient chemical stability; explosion-proofness under operating conditions; suitability of one of the components for cooling the rocket engine; maintenance of the liquid state under operational conditions without undue expense; compatibility with structural materials; a maximum density, minimum toxicity; adequate sources of raw materials. The development of rocket and space technology is based on the use of effective liquid propellants. The most extensively used oxidizers are: liquid OXYGEN, NITROGEN TETROXIDE, NITRIC ACID OXIDIZERS, and hydrogen peroxide; the most frequently used fuels are: KEROSENE, unsymmetrical DIMETHYL HYDRAZINE, HYDRAZINE, liquid HYDROGEN, AMMONIA, AMINES, etc. (the specific impulse obtained is 250—440 s). FLUORINE OXIDIZERS, BORON HYDRIDES, and compositions of liquid propellant components with light metals (lithium and beryllium) are under study as prospective propellant components (the specific impulse produced is 350—500 s).

LIQUID-PROPELLANT ENGINE. A rocket engine firing a liquid propellant. It was suggested by K. E. Tsiolkovsky in 1903. It is the principal engine used today for space flight (see ROCKET ENGINE). The first Soviet liquid-propellant engines, the *OPM* and *OPM-1*, were built and tested at the GDL as far back as 1930—31. In the years that followed the GDL—OKB developed the powerful engines (*РД-107*, *ДР-108*, *РД-119*, *РД-214* and others) which powered the flights of the first satellites of the Earth, the Sun, and the Moon, the first manned space flight and the flights of all Soviet geophysical probes and spacecraft in 1948—68.

A modern liquid-propellant engine comprises a combustion chamber with a nozzle; a turbopump unit; a gas or steam generator; a system of automatic control; a control system; chemical, pyrotechnical or electric ignition; auxiliary units (heat exchangers, mixers, drives); telemetry sensors; a thrust frame, etc. Depending on their designation, liquid-propellant engines may have different characteristics: thrust, from a fraction of gram (microrocket engines) to hundreds of tons; specific impulse, from 150 s for monopropellants to 460 s for bipropellants and up to 500 s for tripropellants; engine weight-to-thrust ratio, from 7 to 20 kg/t; turbopump weight-to-horsepower ratio, from 10 to 40 g/hp; size, from a few cm to several m; weight, from a few g to several t; there are engines with or without provision for repeated firing;as well as with one or several thrust chambers. Rocket power plants may comprise one or several engines. Liquid-propellant engines are principally used to power combat missiles and space vehicles, though sometimes they are also employed as AIRCRAFT ROCKET ENGINES. The propellant may be fed either by pressure, or by pumping. There are pump-fed engines that afterburn the exhaust gas of the turbopump, and those that do not. According to their mission, the engines are classified as sustainers, midcourse correction, retro, and vernier. Microrocket engines can serve for stabilization or orientation of spacecraft, or as personal propulsors. Usually, liquid-propellant engines operate with a permanent pressure in the combustion chamber, but microrockets may function in a pulse mode. Under development are combined turborocket and airbreathing rocket engines which include the

liquid-propellant engine as a component. Depending on the nature of the oxidizer, there are nitric acid, nitrogen tetroxide, oxygen, hydrogen peroxide, fluorine, and other rocket engines.

The major problems in the development of a liquid-propellant engine are: a rational choice of the propellant (see LIQUID PROPELLANT) to meet the specified operational conditions and specific impulse; perfection of the entire process of operation in order to achieve the necessary specific impulse (see MIXING, COMPLETENESS OF COMBUSTION, NOZZLE EFFICIENCY); provision for stable operation at specified rates without developing low-frequency and/or high-frequency pressure oscillations which might cause devastating vibrations of the engine (see SELF-EXCITED VIBRATION, FORCED VIBRATION, MIXING SYSTEM); the cooling of the rocket engine which is subject to aggressive action of combustion products at very high temperatures (up to 5000°K) and pressure (up to hundreds of at) augmented in some instances by the presence of the condensed phase; propellant supply (cryogenic, aggressive, etc.) under pressures reaching, in the case of high-power engines, hundreds of at, and flow rates of several t/s; designing the minimum weight of the engine and its subassemblies which have to carry very heavy loads in operation; high reliability of liquid-propellant engines, especially considering the fact that they are employed for manned space flights and that the frequent practice of using multi-engine power-plants increases the probability of failure (see RELIABILITY OF ROCKET ENGINE). The solution of numerous complex problems arising in the development work on liquid-propellant engines provided the basis for the origination and evolution of rocket and space technology.

LIQUID-PROPELLANT ENGINE WITH AFTERBURNING of generator gas. A rocket engine with pump-feeding of the propellant in which the products of gas generation with a relatively low temperature, obtained from the main propellant, are channelled from the turbine into the rocket engine combustion chamber for afterburning. Such rocket engines do not lose specific impulse for driving the turbopump unit.

LIQUID-PROPELLANT ENGINE WITHOUT AFTERBURNING of generator gas. A rocket engine with pump-feeding of the propellant in which the gas generation products are ejected from the turbopump unit into the surrounding medium through auxiliary nozzles which often serve as verniers. The generator gas is the product of incomplete combustion and has a relatively low temperature, while the auxiliary nozzles have a lower expansion ratio than the main ones. Hence, the specific impulse obtained by the ejection of these products is smaller than that of the main thrust chamber. The mean specific impulse is also smaller, i.e., there is a loss of specific impulse.

LIQUID-PROPELLANT ROCKET. A rocket powered by a liquid-propellant engine. The liquid components of the propellant (oxidizer and fuel) are contained in separate tanks in the propellant compartment of the rocket. A pressure or pump system is used for feeding the propellant into the combustion chamber of the engine. It is the basic type of space rocket.

LIQUID PROPELLANT WITH SEPARATELY FED COMPONENTS. A LIQUID PROPELLANT consisting of two or more components both stored and fed separately into the combustion chamber of the rocket engine.

LIQUID THERMOSTATIC CONTROL of a spacecraft. The maintaining of a pre-determined temperature of coolant in the LSS of a space body during the pre-launch checkout of the vehicle. A specialized ground-based system provides for circulating of coolant in the heat exchangers of temperature control systems.

LITHIUM CHLORIDE, LiCl. A chemical compound used in LSS. Colourless crystals, density 2.0 g/cm^3. Owing to its aptitude for reversible absorption of water vapours it is used in the LSS in moisture gauges and for the preparation of impregnated air driers.

LITHIUM HYDROXIDE, LiOH. Colourless crystals, density 1.46 g/cm^3. Used in the LSS of the American *Mercury*, *Gemini* and *Apollo* capsules as a non-regenerated absorber of carbon dioxide and, partially, moisture. The absorbing power of lithium hydroxide is 0.87 kg of carbon dioxide per 1 kg of lithium hydroxide.

LONG-DISTANCE APPROACH PATH. The path of approach of spacecraft along which their own dimensions are negligible as compared with the distance between them. Angular attitude control is of minor importance on this path and is subordinate to approach control.

LONGITUDE OF NODE. See ORBITAL ELEMENTS.

LONG-PERIOD DISTURBANCES. Disturbances with periods of 100 or more revolutions of the disturbed celestial body. As a rule, their amplitudes are many times greater than those of other periodical disturbances. This explains why long-period disturbances, like SECULAR DISTURBANCES, play such an important role in the evolution of orbits of celestial bodies.

LONG-TERM ACCELERATION. Acceleration active during long periods of launch and re-entry, as well as during manoeuvering in space. The changes in the organism caused by the long-term acceleration depend not only on such parameters of the latter as its magnitude, direction, duration, frequency of action periods and length of intervals between them, but also on the initial functional state of the organism. The first to occur are hemodynamic disturbances, i.e. a different distribution of the circulating volume of blood, whose larger portion accumulates in those parts of the body that are subject to heavier accelerations. This process is accompanied by a deterioration of oxygenation (saturation of blood hemoglobin with oxygen). At launching and re-entry periods the human being can suffer from arterial HYPOXIA. In order to prevent or alleviate the adverse effects of long-term acceleration on hemodynamics, the spaceman is arranged in the spaceship cabin in such a way that the accelerations are directed transversely to his body's longitudinal axis. The optimum direction of the acceleration is at an angle of about 80° to man in the back-to-front plane. Subjectively, long-acting acceleration is percepted as an increase of the body weight, pronounced difficulties in respiration and member movements; sometimes unpleasant sensations in the epigastric, and pains in the retrosternal regions are registered. Long-term acceleration affects also the functioning of the central nervous system which may be attributed to disturbances in cerebral blood supply and to an increased afferentation (signal flow) from internal organs. A long-term acceleration of large magnitude may cause loss of consciousness which is re-established shortly after the action of acceleration is over. Visual disturbances are possi-

ble, too. Under equal circumstances the unsteadiness of the oral analyzer is less pronounced, the function of differentiated reception of information is practically retained. Also possible are disturbances in the vegetative system; systole frequency and blood pressure (at the level of the heart) raise. Considerable changes in the operation of other systems of the body (digestion, secretion, etc.) have also been registered. These changes combine with structural ruptures of various tissues. Those changes in the relative invariability of the organism's internal medium, that have a long after-effect and reflect the new functional level, can predetermine the body's resistivity to habitation under weightlessness. Very effective in preventing such changes are methods of general and special training (stay in Alpine areas, application of centrifuges and other types of special equipment).

LOSSES IN NOZZLE caused by exhaust instabilities. Losses in thrust and SPECIFIC IMPULSE caused by the occurence in the stream at the nozzle exit section of a velocity pattern, the velocities varying in magnitude and direction, a temperature pattern, etc., which lead to losses equalling 1 to 3%.

LOUVER. An element of the temperature control system for opening a greater or lesser portion of the RADIATIVE SURFACE of the spacecraft to control the amount of heat radiated by it. The louver is designed in the form of a slotted cylindrical barrel or as a row of plates arranged over the radiation surface and made to turn about their axes so that the radiation surfaces are either closed or opened.

LOVELL, James (born 1928, Cleveland, Ohio). American astronaut, USNavy captain. After graduation from USA Naval Academy in 1952 served as naval pilot. Upon graduation from the Aviation Safety School at the University of Southern California was an instructor and safety officer at the USNavy Air station, Va. Joined the group of astronauts of the National Aeronautics and Space Administration in 1962. He was the co-pilot on a 14-day orbital flight with F. BORMAN in the *Gemini-7* in December, 1965. He made his second space flight as commander of the *Gemini-12* (with E. ALDRIN). The *Gemini-12* was put into orbit on November 11, 1966, and circled the Earth 59 times in 94 h 30 m. F. Borman and W. ANDERS were Lovell's mates in his third space flight, this time as co-pilot of the *Apollo-8* spaceship on Moon fly-by mission, December 21—27, 1968.

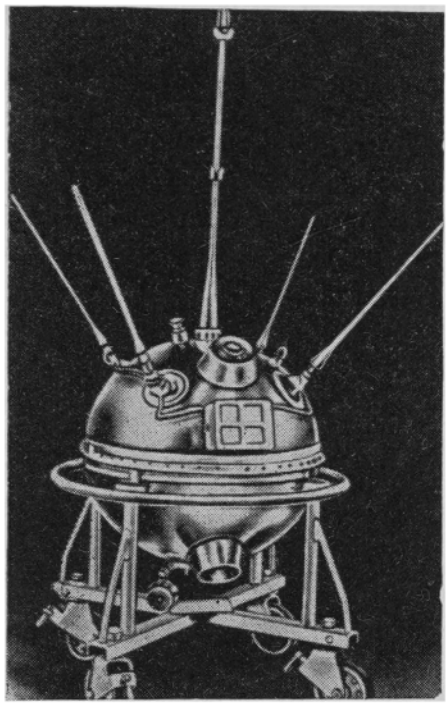
LOW-BOILING PROPELLANT COMPONENT. A component of a liquid propellant (oxidizer or fuel) with a b.p. $\leqslant 25^{\circ}C$ under operating conditions. When stored in stationary or rocket-borne tanks under the pressure of a few atmospheres (depending on the structural strength of the design), certain propellants with a b.p. $>25^{\circ}C$, e.g., nitrogen tetroxide, may be employed as low-boiling ones. Among the low-boiling propellant are liquefied gases (see CRYOGENIC PROPELLANT).

LOW-FREQUENCY OSCILLATIONS. See SELF-EXCITED VIBRATION.

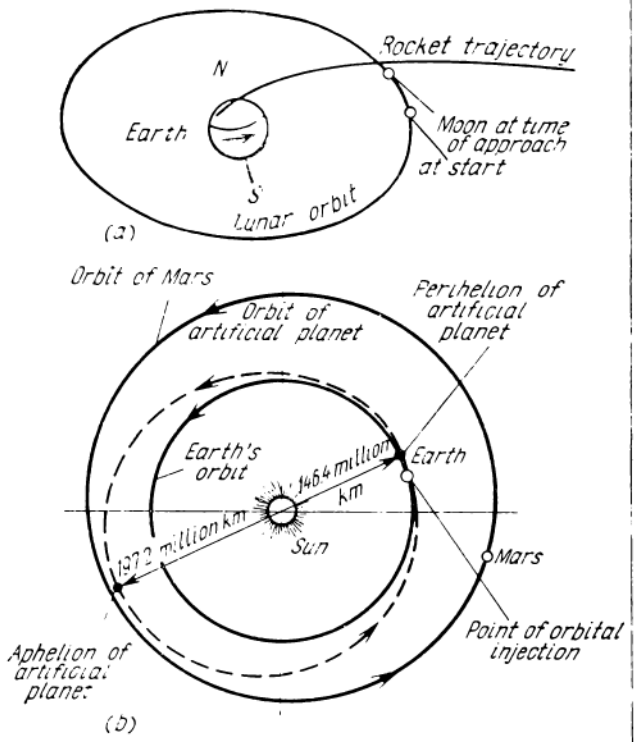
LUNA. The name of a series of automatic interplanetary stations that have been launched by the USSR in the direction of the Moon beginning with 1955. These spacecraft carried out missions involving flight on a near-Moon trajectory (*Luna-1*); Moon landing (*Luna-2*); flight on a circumlunar trajectory and photographing of the Moon (*Luna-3*); soft landing (*Luna-9* and *Luna-13*); orbital flight as lunar satellites (*Luna-10*, *Luna-11*, *Luna-12* and *Luna-14*);

proving of principal concepts connected with flights to the Moon and landing on its surface (*Luna-4* to *Luna-8*).

Luna-1. The world's first automatic interplanetary station launched moonwards on January 2, 1959. After passing close to the Moon, this spacecraft left the Earth's gravitational field and became an artificial planet moving on an orbit about the Sun, making closest approach at 146.4 million km (perihelion) and receding to a maximum distance of 197.2 million km (aphelion). The last stage of the rocket together with the *Luna-1* automatic station weighed 1472 kg. The automatic station contained radio equipment, a telemetering system, five different sets of scientific devices for study of interplanetary space, and other equipment. The last stage of the rocket carried a unit for forming an artificial comet. *Luna-1* was the first spacecraft to reach the SECOND COSMIC VELOCITY. The measurements made during this flight provided new data on the Earth radiation belt and outer space. The *Luna-1* was renamed *Mechta* in world literature.

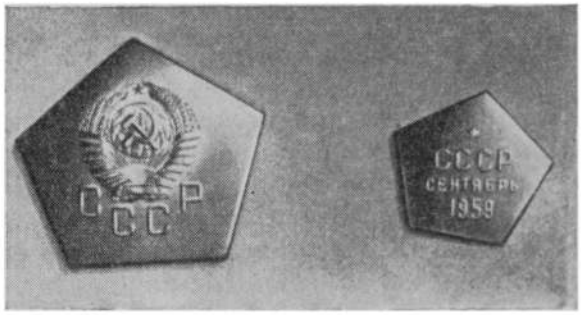


Automatic interplanetary station *Luna-1* (on its assembly dolly).



(*a*) Flight path of the first Soviet space vehicle with the *Luna-1* automatic interplanetary station; (*b*) orbit of the man-made planet relative to the Sun.

Luna-2 was launched by a Soviet space rocket on September 12, 1959, to accomplish the world first flight to another celestial body. *Luna-2* together with the instrument package carried by the last stage of the launch vehicle and containing scientific and measuring instruments had a total weight of 390.2 kg. The instrument package reached the surface of the Moon on Sep-

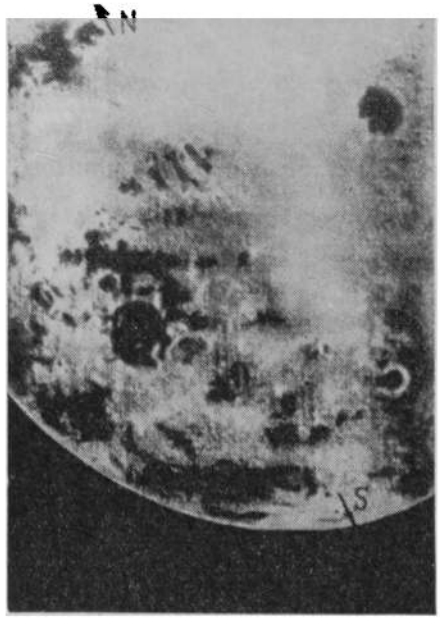


Pennant emblems delivered to the lunar surface on September 14, 1959, by the automatic interplanetary station *Luna-2*.

tember 14, 1959, at 0 h 2 m 24 s Moscow Time, impacting East of the Mare Serenitatis near the Aristides, Archimedes and Autolycus craters. Pennants bearing the Coat of Arms of the USSR were delivered to the surface of the Moon.

Luna-3 was launched on October 4, 1959. The final stage of the rocket weighed 1553 kg, the automatic station weighed 278.5 kg. The *Luna-3* station was equipped with: radio communication and telemetering systems, a TV system with an automatic film processing unit, a set of scientific instruments, systems for orientation relative to the Sun and Moon, solar cells for electric power supply, and a temperature control system. The *Luna-3* was control-

Automatic interplanetary station *Luna-3* (on assembly dolly).



Photograph of the far side of the Moon obtained from *Luna-3* automatic interplanetary station.

led by radio commands from Earth. Moving on a trajectory that bent over the Moon, it made the closest approach to the Moon at 6200 km from its surface and on October 7, 1959, photographed the far side of the Moon. After processing the film, the pictures were transmitted to the Earth by the spacecraft TV system. The *Luna-3* made the first experiment of studying another celestial body by means of spacecraft. After flying round the Moon, the *Luna-3* continued its flight on an elongated elliptical orbit with an apogee of 480 thou. km. After 11 orbits it entered the Earth atmosphere, and ceased to exist.

In order to make further exploration of the Moon and to solve the problem of soft landing of the instrument container on lunar surface, five spacecraft were launched from a Soviet space centre in 1963—1965: *Luna-4*, *Luna-5*, *Luna-6*, *Luna-7*, and *Luna-8*.

Luna-5 reached the surface of the Moon on May 12, 1965. First tentative data on operation of the system of soft landing were obtained.

Luna-7 reached the surface of the Moon on October 8, 1965.

Luna-8 landed on the Moon on December 7, 1965. This crowned the experimental development programme of the system of star orientation, control of space-borne radio equipment, radio control of flight trajectory, and instruments of space-borne flight control system.

Luna-9 was the first spacecraft to make a successful soft landing on the Moon and transmit pictures of the lunar landscape back to Earth. It was launched on January 31, 1966, and landed on February 3 at 21 h 45 m 30 s, Moscow Time, in the region of Oceanus Procellarum (the coordinates of the point of impact are 60°22′ W. Long. 7°08′ N. Lat.). The TV system transmitted three panoramas of lunar landscape (at different angles of the Sun over the horizon) to Earth. Seven radio contacts were held to transmit scientific data. *Luna-9* comprised an automatic lunar station combined with a service module carrying the control equipment and an engine for mid-course correction and landing deceleration. After injection into the moonward flight path, the overall weight of the automatic interplanetary station was 1583 kg, after landing it weighed 100 kg. The sealed package contained TV and radio

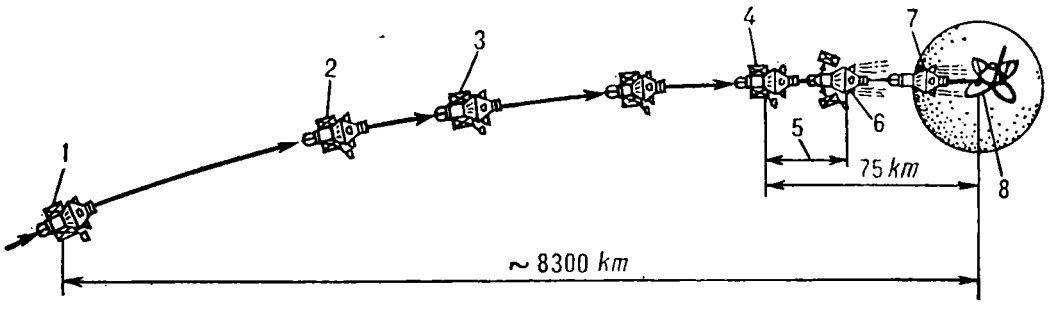
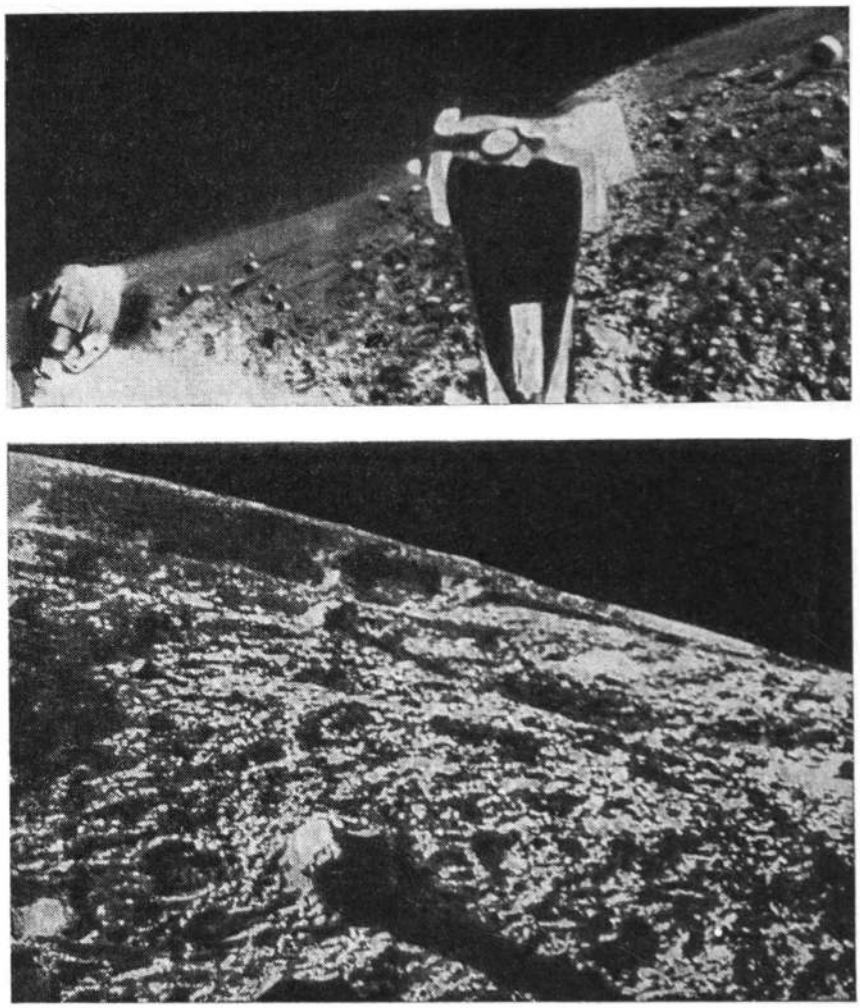


Diagram of flight path of the *Luna-9* automatic interplanetary station on access to the Moon.

1—plotting lunar vertical; *2*—orienting the rocket engine axis on lunar vertical; *3*—energizing radio altimeter; *4*—command of radio altimeter for starting rocket engine; *5*—time required for engine firing; *6*—engine fired; separation of clustered compartments; *7*—engine automatically cut off; *8*—automatic lunar station is separated from rocket engine unit and softly landed on lunar surface.



Photographs of the lunar landscape relayed to the Earth by the Soviet automatic interplanetary station *Luna-9* (visible in the foreground of the first photograph are parts of the station).

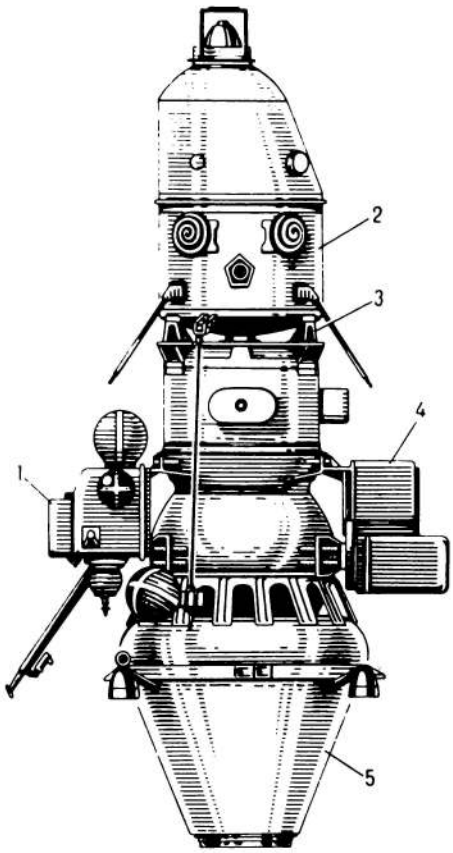
communication equipment, a programming unit, a set of scientific instruments, a temperature control system, and sources of electric power. The equipment was controlled by command from Earth. The photographs of the lunar surface obtained by this experiment and the successful soft landing have a significant bearing on future flights to the Moon, including manned flights.

Luna-10, launched on March 31, 1966, was the first man-made lunar satellite. The automatic interplanetary station weighed 1600 kg. It consisted of the lunar satellite capsule, the equipment compartments, and a rocket engine to manoeuvre the station into a selenocentric orbit. The automatic station in orbit about the Moon weighed 245 kg. The circumlunar orbit had a perilune (minimum distance from Moon) of 350 km and an apolune (maximum

Pennant and the Soviet Coat of Arms delivered to the lunar surface by the automatic interplanetary station *Luna-9* on February *3*, 1966.

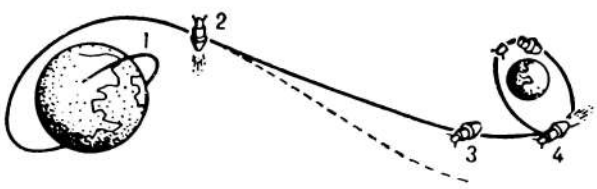
Automatic interplanetary station *Luna-10*.

1—radio equipment and scientific measuring instruments; *2*—artificial lunar satellite; *3*—satellite separation arrangement; *4*—astro-orientation system devices; *5*—rocket engine.



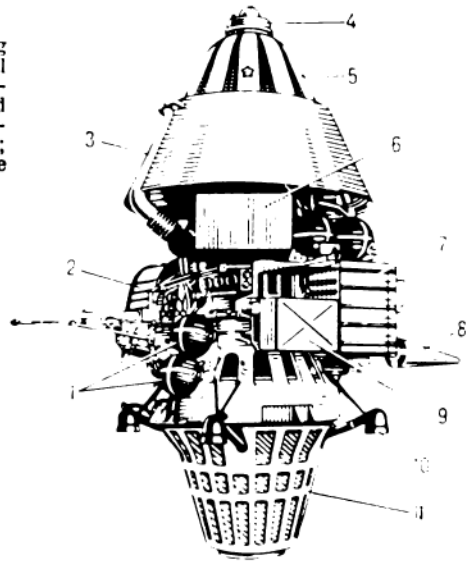
Schematic diagram of flight path of the automatic interplanetary station *Luna-10*.

1—midcourse (parking) near-Earth orbit; *2*—correction of flight path to the Moon; *3*—orientating *Luna-10* prior to deceleration; *4*—deceleration and injection into circumlunar orbit.

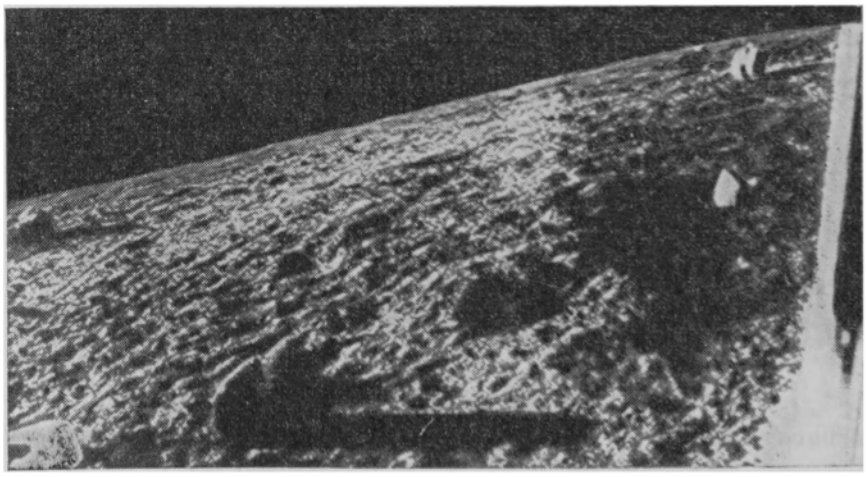


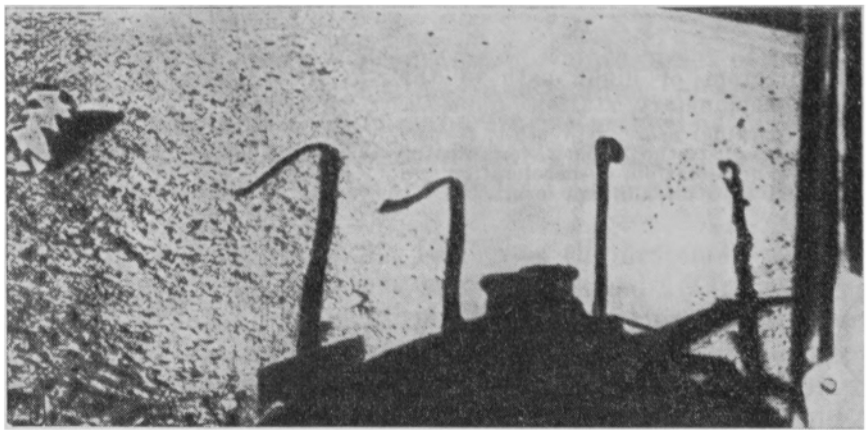
Automatic interplanetary station *Luna-12*.

1—gas bottles of astro-orientation system actuating members; *2*—TV equipment; *3*—temperature control system radiator; *4*—radiometer; *5*—instruments compartment; *6*—chemical battery; *7*—optical and mechanical unit of astro-orientation system; *8*—antenna; *9*—electronic unit of astroorientation system; *10*—control rocket engines; *11*—retro-rocket engine for trajectory correction.



Fragments of lunar panorama relayed to the Earth by Soviet automatic interplanetary station *Luna-13*. The shadow of the station can be seen in the lower photo.



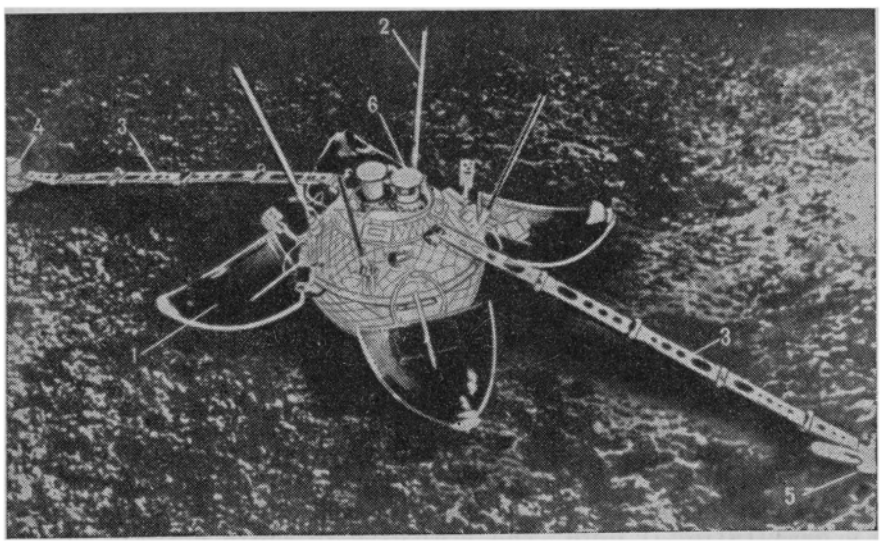


distance from Moon) of 1017 km, the angle of inclination was 71°54′. The station's active life continued up to May 30, 1966; during this time it completed 460 orbits round the Moon, a total of 219 radio contacts were held. Data were obtained on near-Moon space and indirect information on composition of lunar surface rocks. It broadcasted the *International* several times, the first time being during a session of the 23rd Congress of the Communist Party of the Soviet Union.

Luna-11 was the second Soviet artificial lunar satellite launched moonward on August 24, 1966. The perilune was 160 km, apolune, 1200 km, and inclination, 27°. The station carried a set of equipment for study of the circumlunar space and the Moon.

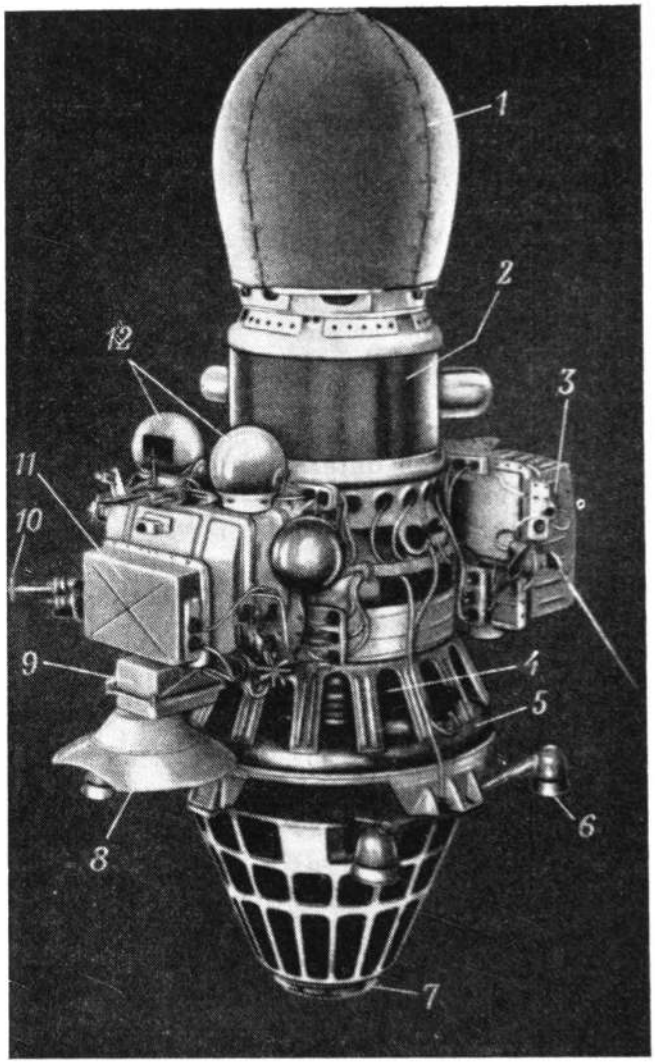
Luna-12 was the third Soviet lunar satellite launched on October 22, 1966. The perilune was about 100 km, the apolune was 1740 km. Besides carrying a set of scientific instruments, the satellite carried a TV system of high resolution (1100 lines) which obtained and transmitted to Earth large-scale pictures of lunar surface in the regions of Mare Imbrium, the Aristarchus crater, and other areas. The resolution was high enough to discern craters with diameters of 15 to 20 m.

Luna-13 was the third Soviet interplanetary station to make a soft landing on the Moon. It was launched towards the Moon on December 21, 1966. It landed on December 24 in the region of Oceanus Procellarum (at a site with coordinates 62°03′ W. Long., 18°52′ N. Lat.). The station carried scientific instruments (mechanical soil-measuring penetrometer, dynamograph, and radiation densitometer), that made it possible to send back to Earth unique data on the mechanical and physical properties of the outer layer of the lunar surface, as well as the cosmic-ray reflectivity of the lunar surface. The TV system transmitted back to Earth panoramas of lunar landscape



Automatic lunar station *Luna-13*.

1—petal-type antennas; *2*—rod antennas; *3*—mechanism for advancing instruments to outboard position; *4*—mechanical ground tester; *5*—radiation density meter; *6*—TV camera.



Luna-9 mounted on automatic interplanetary station.

1 — *Luna-9* station; *2* — control system module; *3* — equipment of astro-orientation system; *4* — oxidizer tank; *5* — fuel tank; *6* — vernier engine; *7* — liquid-propellant engine; *8* — radio altimeter antenna; *9* — radio altimeter; *10* — micro-engine; *11* — equipment of radio measurement system; *12* — gas bottles of astro-orientation system

at different angles of the Sun over the horizon.

Luna-14 was the 4th Soviet lunar satellite launched on April 7, 1968, into an orbit with a perilune of 160 km, apolune of 870 km and inclination of 42°. The period of revolution was 2 h 40 m. *Luna-14* was designed to make more accurate relative measurements of the Earth and Moon masses, the Moon's gravitational field, the stability of radio signals sent to spacecraft at different locations in respect to the Moon, to register cosmic rays and fluxes of charged particles emanating from the Sun, and to obtain additional information for construction of a precise theory of motion of the Moon.

LUNAR EXPEDITION. The flight of a manned spaceship to the Moon, landing on the Moon, and subsequent return to Earth. A number of projects to accomplish this have been published in recent years. In the USA the *Apollo* spaceship is being developed for a lunar expedition.

LUNAR METEOROLOGICAL OBSERVATORY. An automatic lunar station intended for continuous observation of meteorological processes occurring in the Earth's atmosphere, measurement of the Earth radiation with the view of solving the REVERSE PROBLEMS OF SATELLITE METEOROLOGY, as well as study of the Moon's heat balance.

LUNAR ORBITER. The name of a series of American lunar satellites. These spacecraft have an initial weight of 386 kg. On injection into a selenocentric orbit, the satellite weighs about 270 kg. A rocket engine with a thrust of 45 kg injects the satellite into orbit and makes the necessary corrections. This satellite carries a TV system for taking pictures of the lunar surface from orbit, processing the film, and relaying the pictures to Earth by video channel. The system has long-focus and short-focus lenses. *Lunar Orbiter-1* was launched on a selenocentric orbit with an apolune of 1867 km and a perilune of 192 km on August 10, 1966. By a corrective manoeuvre on orbit, the perilune was reduced to 40 km. While in orbit, this satellite took pictures of several points on the lunar surface and carried out a programme of scientific experiments. On November 6, 1966, *Lunar Orbiter-2* was launched, followed by *Lunar Orbiter-3* on February 5, 1967. The photographs transmitted to Earth by these satellites are of high scientific value. Care was taken during these flights to obtain pictures of areas for the landing of future lunar expeditions. *Lunar Orbiter-4* was launched on a high selenocentric orbit (altitude from 2700 km to 6100 km) on May 4, 1967. It took smaller scale photographs of the lunar surface, including areas of the far side of the Moon photographed previously by the Soviet lunar satellite *Luna-3* and *Zond-3*. *Lunar Orbiter-5* was launched on August 1, 1967, for the purpose of photographing a number of areas of both the visible and the far sides of the Moon, including polar regions. Its orbit had a perilune of 196 km, apolune of 6050 km, and inclination $\sim 85^\circ$ (after correction the perilune became ~ 100 km, and apolune, ~ 1500 km). In October, 1967, *Lunar Orbiter-5* was shifted to a higher orbit. The orbital life-time of these satellites was up to 11 months. Besides photography, their purpose was to study radiation and micro-meteorites in circumlunar space, and also the Moon's field of gravity (by observing the evolution of orbits).

LUNAR SURFACE VEHICLE, self-propelled. A vehicle capable of self-propelled motion and intended for transporting the crew and any necessary equipment over the surface of the Moon. Literature describes numerous different types of roving lunar vehicles (e.g., the American *Molab* project). It has been proposed that these vehicles have large-diameter wheels or be crawler-mounted for travel over the rough lunar terrain. An automatic vehicle could be operated by radio signals from Earth. In this case a TV system would be necessary to give the operator on Earth a continuous view of the locality in front of the vehicle. If manned, such a vehicle could be controlled directly by spacemen.

M

MACH NUMBER (M number). The ratio of the velocity of an object, e.g., an aircraft or spacecraft, to the speed of sound in the ambient environment, or, in case of gas motion, the ratio of the gas speed to the local speed of sound (i.e., the speed of sound in the given point).

MAGNETIC FIELDS IN SPACE. The magnetic fields existing in space. The intensity of the magnetic field in the vicinity of the magnetic poles of the Earth is of the order of 0.5 oe. The Sun generally has a weak magnetic field whose intensity does not exceed a few oe. The magnetic field intensity of sunspots has been measured at 3 to 4 thou. oe; that of active regions amounts to several tens of thousands of oersteds. At present, the magnetic fields of the Moon and planets are under careful study. Certain data are given in the articles on MOON and respective planets. In interplanetary space, magnetic fields are associated mainly with the SOLAR WIND. They have intensities of the order of 10^{-4}—10^{-5} oe. Meteorites have exhibited residual magnetism indicating that they were once "magnetized" in a field of about 0.2 oe. That might have been the magnetic field of the hypothetical planet Phaeton, whose desintegration gave birth to the asteroids and meteorites.

MAGNETIC SENSOR OF ORIENTATION. An instrument that serves for determining the angular position of spacecraft axes with respect to the lines of the magnetic field of the nearby planet. This sensor is used as a position pick-off in certain systems of satellite orientation.

MAGNETIC STORMS. The most violent disturbances of the Earth's magnetic field, with amplitudes up to hundreds and thousands of gammas (1 gamma = $= 10^{-5}$ oe; the geomagnetic intensity at the equator is about 0.4 oe) (see TERRESTRIAL MAGNETISM). Magnetic disturbances, denoted by the symbol D, are part of the geomagnetic variations obtained by subtracting from them the periodic field variations (solar and lunar daily magnetic variations). The morphology of the D field, i.e., its space distribution as a function of time, has served as the basis for a number of statistical and physical classifications of disturbances. One of the most characteristic types of disturbances is the so-called aperiodic disturbance variation (the variation with the time of the storm) D_{st}, beginning simultaneously all over the Earth's surface and proceeding more or less equally at all points of the Earth's surface although considerable irregular effects of local origin can be observed on magnetic records (magnetograms) at some observatories. Such storms last from 2 to 3 days; the highest intensity is observed in several initial hours of the storm.

Many magnetic storms (practically all violent storms) begin suddenly and simultaneously (within about 1 m) all over the Earth. However, some magnetic storms arise gradually. The beginning of a magnetic storm is characterized by a growing intensity of the geomagnetic field (the initial phase of the storm); it can last for several hours. The next period is the main phase during which the field intensity decreases and reaches a minimum and then slowly returns to normal (the restoration phase). This behaviour is most pronounced in the horizontal variations of the geomagnetic field. Local disturbances are often of the same character too, but their intensity substantially depends on the geomagnetic latitude and local time: their maximum intensity occurs in the auroral zones (~67°) so they are often called polar

disturbances *DP*. Below and above this zone the *DP* disturbances look like more or less gradual deflections from the initial level and resemble the curve of a sea bay, so such disturbances were named magnetic bays. Especially intensive bay disturbances arise during magnetic storms; they can last for 1—2 h. One magnetic storm arising suddenly and having a main phase may be accompanied by several magnetic bays; in this case each disturbance of this kind is called a polar substorm. Part of the disturbance may consist of a rise in the amplitude of the daily variations (the disturbance daily variations D_s). It is not clear as yet whether D_s is related to magnetic bays or not.

Magnetic storms

In addition to magnetic bays there are other kinds of disturbances, e.g., micro-pulsations or short-period oscillations (SPO) of the electromagnetic field of the Earth with relatively short periods and small amplitudes. An example of SPO are the so-called "pearls" (beat surges lasting for several minutes with a period of 1—4 s within a series) or giant pulsations lasting for up to several hours (the periods within a series are 40—150 s, amplitudes are up to 30—40 gammas). There is another kind of slight magnetic disturbance, the so-called "crochets", appearing on the magnetograms as steep pulses and produced by an increase of ionization of the Earth's atmosphere on the side illuminated by the Sun due to UV and X-ray radiation of solar flares.

The theoretical and experimental investigation of recent years and especially the results of direct exploration of the near-Earth and interplanetary space with the help of satellites and sondes have radically changed our conceptions of magnetic storms. A conception has been developed of the Earth's magnetosphere as a region of space occupied by the geomagnetic field and for which a high degree of ionization, practical absence of collisions of particles and capture of charged particles by the geomagnetic field are essential features. According to concepts of magnetohydrodynamics, the observed geomagnetic disturbances are due to compression, expansion and other deformations of the magnetosphere.

Up-to-date theories ascribe the development of magnetic storms and the phenomena related to them to magnification of the influence of solar plasma flows in the Earth's magnetosphere. The increase of the horizontal magnetic intensity is ascribed to the compression of the geomagnetic field due to the increased pressure of the plasma flow. This compression is equivalent to the appearance at the boundary of the magnetosphere of a system of electric currents attributable to the difference in motion of oppositely charged plasma particles in the geomagnetic field in this region. In the equatorial plane the current flows eastward; the current is closed above and below the equatorial plane (a westward current). This system of electric currents and their field are usually denoted as *DCF* (*D* for disturbance, *CF* for corpuscular flow). The main phase of the magnetic storm (a decrease in the horizontal magnetic intensity) is the result of an increase in the number of charged particles (or their energy) inside the magnetosphere. The deformation (expansion or "swelling" of the magnetosphere), due to the motion of these particles (twisting around the geomagnetic lines of force, longitudinal oscillations between the reflection points in the northern and southern hemisphere, drifting around the Earth across magnetic lines—see RADIATION BELT OF EARTH), is equivalent

to the appearance in the magnetosphere of an electric current flowing westward, called a ring current.

The ring current and its field are usually denoted as *DR* (*D* for disturbance, *R* for ring). Both the *DCF* and *DR* outer fields are almost uniform near the Earth, although variations in these fields induce geoelectric currents whose field is non-uniform. To explain the main phase of a magnetic storm, the formation of the so-called trail of the Earth's magnetosphere or of the corresponding current system, which is its equivalent, is assumed to be of great importance. The sweeping of the geomagnetic lines of force away from the sides of the magnetosphere to the trail means that the remaining field gains additional space for its expansion (the mean phase, a decrease of the field). The two mechanisms may occur simultaneously in varying proportions. Polar disturbances (magnetic bays) due to current systems (situated mainly in the high latitudes) are more pronounced in the dark hemisphere. The concentration of currents is especially strong along the auroral zones (polar or auroral electrostreams). These currents and the associated field are usually denoted *DP* (*D* for disturbance, *P* for polar). The current is mainly directed westward (above the dark hemisphere and the morning sector) and sometimes eastward (usually over the midday sector and toward the evening). The current is closed mainly above the auroral zones (over the polar caps) and partially in the lower latitudes.

The appearance of *DP* current systems is attributed to penetration into the ionosphere of high-energy particles (possibly protons of 100—200 keV). Other field disturbances can be produced by magnetohydrodynamical waves propagating inside the magnetosphere to the Earth's surface, and by the interaction of these waves with charged particles in the Earth's magnetosphere. Many properties of the geomagnetic disturbances and their interdependence are not yet understood well enough. Only complex investigations, including direct methods and observations at the ground, will make it possible to solve these problems, and their adequate understanding will largely promote the explanation of aurorae polares, ionospheric heating and ionization, acceleration of charged particles, and other phenomena interrelated with magnetic storms.

The main problem of the magnetic storm theory is to explain the mechanism of introduction of additional energy into the magnetosphere. The dissipation of energy in the Earth's magnetosphere during an intensive magnetic storm is 10^{19}—10^{20} erg/s. Such an energy feed can be accomplished either by direct injection of solar plasma (e.g., through the neutral points) or by means of acceleration of particles relative to the cold plasma of the magnetosphere. An important role in determining the degree of geoeffectivity of solar plasma flows appears to be played by the magnetic field of these flows (e.g., the mutual orientation of the plasma flow field and the geomagnetic field).

MAGNETIC TRAIL (magnetic tail of the Earth). The region of geomagnetic lines of force "swept" by the SOLAR WIND to the dark side of the Earth (see GEOMAGNETIC TRAP). The diameter of the magnetic trail cross section is assumed to be 40 Earth radii. Direct measurements have shown that the magnetic trail stretches at least as far as the lunar orbit, but it is

not clear whether its lines of force are closed at a still greater distance from the Earth, forming the boundary between the geomagnetic field and the solar wind, or join the lines of force of interplanetary magnetic field. The northern and southern halves of the magnetic trail are separated approximately in the ECLIPTIC plane by a neutral layer, a region of lower intensity of the magnetic field. The intensity of the magnetic field in the centre of the layer is probably equal to zero. The characteristic size (thickness) of the neutral layer is presumably a fraction of the Earth's radius. The field intensity in the magnetic trail is about 15 gammas at the distance of 30 Earth radii. The possible cause of steady existence of the magnetic trail and the neutral layer is a complex system of currents; however, most of the suggested models of the magnetic trail do not explain the origin of these currents; the role of the magnetic trail in the origin of various geophysical phenomena is not clear either.

MAGNETISM OF INTERPLANETARY SPACE. The magnetic field in interplanetary space that was discovered through direct measurement performed by automatic interplanetary stations. The existence of magnetism of interplanetary space was also inferred from indirect data (variations of cosmic rays). Careful observations with the help of magnetographs obtained by a number of automatic interplanetary stations and satellites have established that magnetism of interplanetary space during calm periods is due to permanent radial flows of solar plasma (a steady SOLAR WIND). The vector of the magnetic field (of an intensity of the order of $5 \cdot 10^{-5}$ oe) substantially deflects from the radial direction because the field is transferred relative to the rotating Sun by radially moving plasma. Observations have shown that in the presence of geoeffective solar corpuscular flows magnetism of interplanetary space increases several times. Complex variations of the magnetic vector are determined by the structure of the solar corpuscular flow. The magnetism of interplanetary space determines the paths of galactic cosmic rays, especially solar cosmic rays, and probably the nature of interaction between solar corpuscular flows and the magnetosphere of the Earth.

MAGNETISM OF PLANETS is determined by direct measurements with the help of space rockets flying close to the planets Venus and Mars, and also by indirect observations of radio radiation of Jupiter and Saturn and of propagation of solar cosmic rays near Mercury. Direct measurements of the magnetism of planets have established that Venus and Mars show no general magnetic field, within experimental accuracy: for Venus $M_{♀}/M_{♁} \leqslant 10^{-4}$, for Mars $M_{♂}/M_{♁} \leqslant 2 \cdot 10^{-4}$, where $M_{♀}$, $M_{♁}$ and $M_{♂}$ are the magnetic moments of Venus, the Earth and Mars, respectively. Therefore these planets have no radiation belts. Radioastronomical observations have shown that Jupiter has a magnetic field of the order of 5—10 oe. The effective magnetic dipole of Jupiter must be displaced relative to the axis and the center of the planet (approximately by 1/3 of the radius in the equatorial plane). Radioastronomical observations of Saturn have also confirmed the presence of a general magnetic field on it. Experimental data on the magnetism of other planets have not as yet been obtained.

MAGNETOHYDRODYNAMIC GENERATOR. A source of electric current generated by the motion of a gaseous electrically conducting working fluid

Magneto-hydro-dynamic rocket engine

(plasma) or molten metal in a magnetic field. Magnetohydrodynamic generators have no moving parts. Their efficiency is high. It has been proposed to employ magnetohydrodynamic generators for energy supply to electric rocket engines and space-borne electrical equipment.

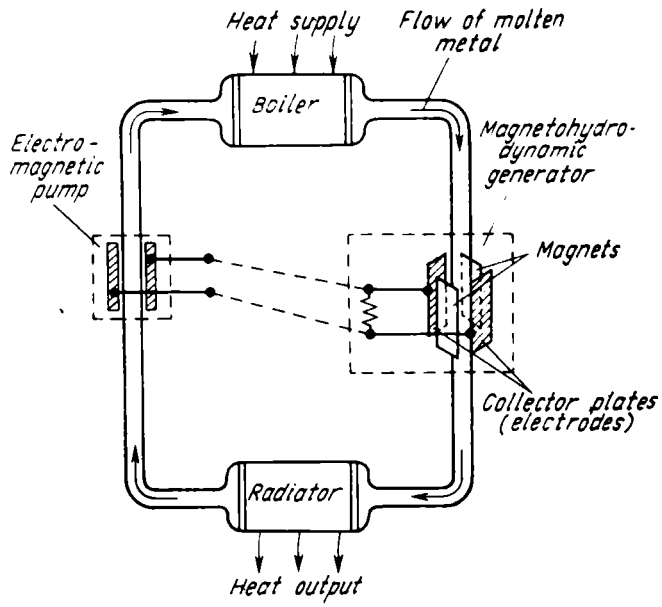


Diagram of magnetohydrodynamic generator.

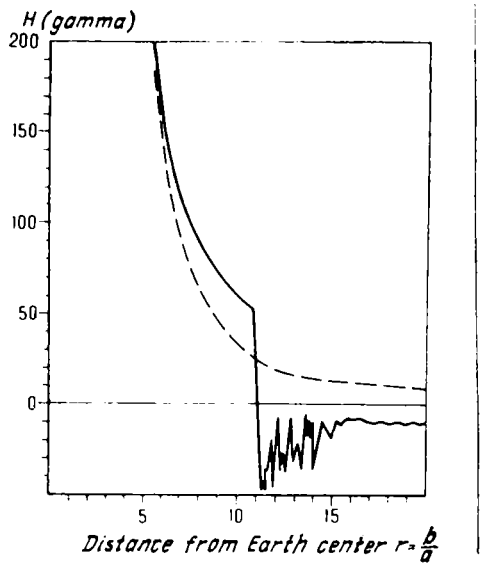
MAGNETOHYDRODYNAMIC ROCKET ENGINE. See ELECTROMAGNETIC ROCKET ENGINE.

MAGNETOHYDRODYNAMICS. Deals with the flow of conducting fluids in a magnetic field. Magnetohydrodynamics is the theoretical basis for the study of interstellar gas motion (space magnetohydrodynamics), of many processes in power and aerospace engineering, in particular, of the performance of hypersonic aircraft and spacecraft (especially during re-entry), and of processes occurring in ELECTRICAL ROCKET ENGINES, magnetohydrodynamic generators, etc.

MAGNETOPAUSE. The boundary of the MAGNETOSPHERE including the boundary layer. Magnetopause is characterized by that the geomagnetic field intensity sharply drops to zero, the field strength vector changes its orientation, and a transition arises to a region with a chaotic (random) magnetic field within which the geomagnetic field presumably passes into interplanetary magnetic field. On the daylight side in the equatorial plane of the Earth, the magnetopause occupies usually a few hundred km, while the transient region between magnetopause and the outgoing magnetohydrodynamic shock wave (see Fig. in GEOMAGNETIC TRAP) extends over 2—4 Earth radii. The field acquires a more regular character after passage through the shock wave front into the region of interplanetary plasma; the average value of the field intensity within the transient region is several times greater than that of the interplanetary field. Exploration by means

of satellites indicates that the flow of plasma within the region of the magnetopause is of a very complex nature and a more through theoretical study of this phenomenon is needed.

MAGNETOSPHERE of the Earth. The region occupied by the geomagnetic field around which SOLAR WIND flows



Variation of geomagnetic field versus distance from Earth. The dashed line shows variation of dipole-generated magnetic field, the continuous line, the variation of real geomagnetic field. H is intensity of geomagnetic field; $r=\frac{b}{a}$ is distance from Earth center, where b is equatorial distance from Earth center, a is Earth's radius, km.

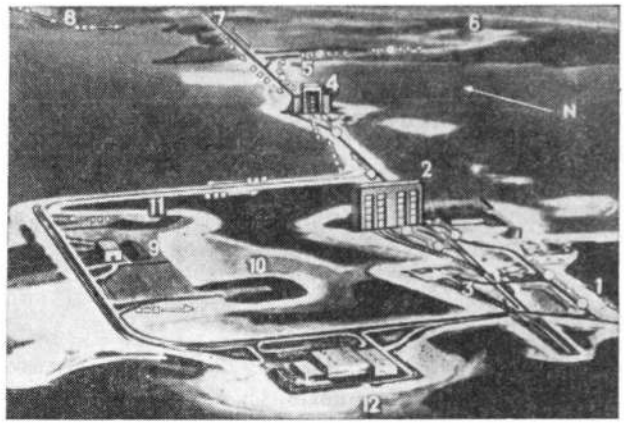
(see Fig. in GEOMAGNETIC TRAP). The magnetosphere includes an inner (closed) approximately dipole field zone that is a geomagnetic trap for charged particles and an outer zone comprising magnetic lines of force that are "swept" by the solar wind from the sunlit to the dark side of the Earth where they form the Earth's MAGNETIC TRAIL.

The main condition determining the position of the magnetosphere boundaries is the equality of the static pressure of the Earth's magnetic field and the kinetic pressure of the solar wind. If the solar wind is an ideal conducting medium without any magnetic field, the geomagnetic field cannot penetrate into it and the boundary layer is to be very thin.

The intensity of the magnetic field within the boundary layer increases (as compared with the dipole field) due to the fact that the field of the boundary currents set up by the solar wind particles is superimposed on the geomagnetic field. The geomagnetic field is to be fully neutralized by the boundary current field outside the magnetosphere and the boundary layer. However, the presence of an interplanetary magnetic field within the solar wind and other factors diffuse the boundary layer of the magnetosphere.

MAINTENANCE AREA. A complex of structures at a space centre comprising general-purpose technical equipment, ground operating equipment, as well as a specially prepared plot of land with transport ways that is used to accept, store and assemble launch vehicles and space bodies, to test them, to fill the space bodies and to mate them to the vehicles. (See Fig., p. 246).

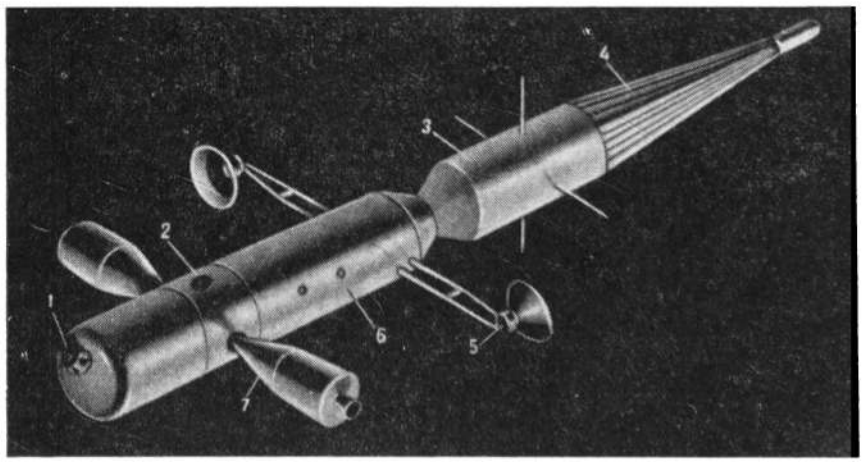
MANNED ORBITAL STATION. A massive Earth satellite with crew on board, intended for long orbital operation. Such a station will have its crew brought up and replaced periodically by means of a special space ferry. The manned orbital station will be able to carry a large amount of different types of equipment to be directly operated by the crew. This permits it to be used to solve many problems of pure and applied science, such as to conduct the study of circumterrestrial space and the Earth, to take astronomical, radio-astronomical, and meteorological observations, to render a naviga-



Maintenance area.

1—hard-surface road for delivering liquid-propellant stages of the launch vehicle central unit to vertical assembly building; *2*—vertical assembly building; *3*—launch pad repair and maintenance site; *4*—building for assembly of solid-propellant boosters and their mating to rocket central; *5*—liquid-propellant storage area; *6*, *7*—launch complexes; *8*—railway for delivering solid-propellant boosters to maintenance area; *9*—building for inspection and check-out of solid-propellant boosters; *10*—storage area for solid-propellant boosters; *11*—building for maintenance of solid-propellant boosters; *12*—storage of rocket elements.

tional aid, to investigate the behaviour of materials and equipment in outer space, to perform military missions, etc. Manned orbital stations might also be used as bases for space assembly of heavy spaceships. In recent years



One of probable versions of manned orbital stations.

1—astronomical equipment compartment; *2*—air-lock compartment; *3*—control instrumentation compartment; *4*—nuclear power unit; *5*—antennas; *6*—crew cabin; *7*—cargo spaceship.

several projects for orbital stations have been made public, their crews numbering from 2–3 up to scores of men.

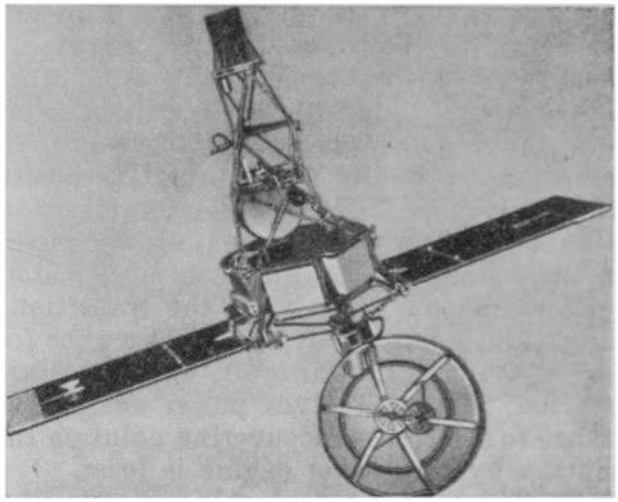
MANOEUVRE. An intentional change in the flight trajectory of spacecraft for transferring it from one (initial) orbit into another (final) orbit, e.g., the

transfer of an Earth satellite from an inclined into an equatorial orbit, launching of a spacecraft to the Moon from an Earth satellite orbit, placing of a lunar spacecraft into a lunar orbit at approach to the Moon, docking of two spacecraft in outer space, etc. Particular cases of manoeuvering are TRAJECTORY CORRECTION of spacecraft and CORRECTION OF ORBITS of Earth satellites. Depending on the relative positions of the initial and final orbits, the manoeuvre may be performed either in an orbital plane (in this case the planes of the initial and final orbits coincide), or may bring about a change in the plane of the orbit. The most widely used method of manoeuvering is pulse manoeuvering when the transition into a new orbit is performed by short-time operation of the rocket engine (once or, in complicated cases, several times). Unlike aircraft, to manoeuvre a spacecraft its engine must be started, which involves power consumption. Therefore, it is of prime importance to select a manoeuvering point on the trajectory where the power consumption by the rocket engine is least.

MANUAL CONTROL. The mode of spaceship control, when certain control functions are within the scope of automatic devices, whereas other functions are taken over by the crew. Automatic control devices ensure a higher speed of operation and accuracy of control and possess a better response than is attainable when the controls are taken over by the pilot. Nevertheless, they are inferior as regards their ability of ensuring proper all-round supervision of the space-borne systems, comparing and analyzing the received information and adopting an optimum mode of operation in cases not provided for by the basic program. Consequently, manual control is more reliable than a completely automated system. Man's capacity of finding a proper solution to certain specific problems is greater than that of automatic devices. Thus, after slight training man is able to find quickly any star required for solving navigational problems and orientation in space; at present, automatic devices used for this purpose are of very complicated design (especially in cases when a faint star is to be found). On the other hand, the pilot cannot be made fully responsible for overall control of the spaceship, since this requires simultaneous control of a great number of diverse quantities (e.g., control of the angular attitude of the spaceship calls for synchronous control of 3 angular coordinates and 3 angular velocities). Therefore, certain control functions have to remain within the scope of automatic devices.

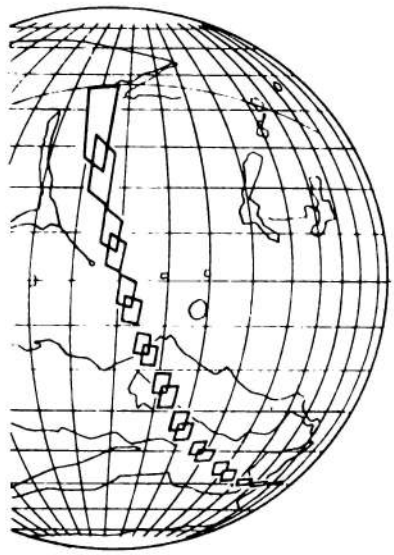
MANUAL ORIENTATION. Attitude control of spaceship effected by the spaceman in free flight. Manual orientation systems often employ auxiliary devices that make it easier to pilot the spaceship, e.g., angular-rate sensors that indicate the rate of rotation of the spaceship when the control lever is long kept shifted.

MARINER. The name of a series of American automatic spacecraft intended for fly-by missions to Venus and Mars, also the name applied to the program for these flights. These spacecraft have a weight of about 260 kg, the equipment being arranged in an unsealed structure. Solar cells supply the electric power. Their equipment includes an astro-orientation system, a vernier engine for midcourse correction and manoeuvering, and a set of scientific instruments (including a TV system designed for recording and later relaying of the pictures to the Earth) for study of the planet they pass



Mariner automatic interplanetary station

by and interplanetary space. The launch vehicle is *Atlas-Centaur*. *Mariner-2* spacecraft was launched on August 27, 1962, in the direction of Venus, and on December 14 it flew at ~ 35,000 km from the planet. This flight yielded certain data on the temperature, magnetic field, and composition of the atmosphere of Venus, as well as a more exact estimation of its mass. *Mariner-4* spacecraft was started in the direction of Mars on November 28, 1964, and on July 15, 1965, passed at ~ 10,000 km from it. This was the first spacecraft to photograph the surface of Mars. The shots numbered 22 and were taken in different regions of Mars. This flight also yielded much valuable scientific data. *Mariner-5* was sent in the direction of Venus on June 14, 1967. Its mission was to collect data about the planet's atmosphere, radiation belt and magnetic field. *Mariner-6* started towards Mars on February 24, 1969; it carries a set of scientific instruments for measurement of the density, pressure, chemical composition, and temperature of martian atmosphere, and the planet's surface temperature; it is also equipped with two TV cameras that will transmit views of martian landscape. The spacecraft should pass at a distance of several thou. km from Mars on July 31, 1969. *Mariner-7* was launched on March 27, 1969; it houses the same equipment as *Mariner-6*. Its closest approach of Mars is expected on



Regions on Mars photographed by *Mariner-4*.

August 5, 1969. It is expected to pass over the southern hemisphere of Mars, while *Mariner-6* will fly over the equatorial part. The launches of *Mariner-1* and *Mariner-3* proved unsuccessful.

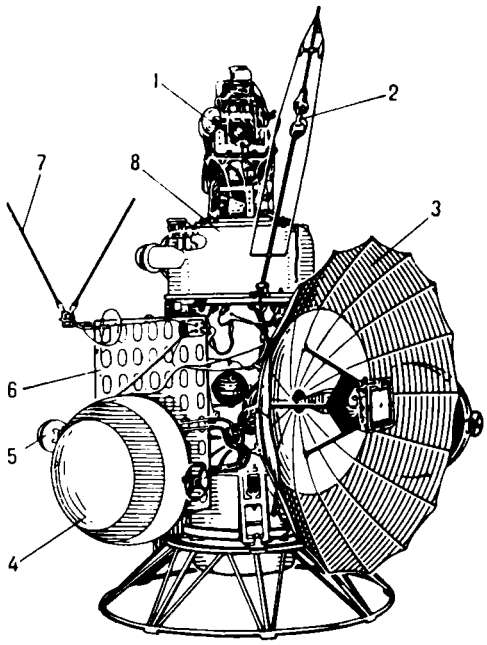
MARS. The fourth principal planet from the Sun in the solar system. Its mean distance from the Sun is 1.524 A.U. (227.8 million km). It travels on an orbit with an eccentricity of 0.093, a perihelion of 206 million km, an aphelion of 249 million km, and an inclination of 1°51′ to the ecliptic. The distances of Mars from the Earth in oppositions are 56 and 102 million km. Other data characterizing Mars are: sidereal period of revolution is 686 days 23 h 31 min; equatorial radius 3395 km; polar oblateness 1 : 192; sidereal period of rotation 24 h 37 min 22.58 s; inclination of equatorial plane to orbital plane 24°48′ produces seasonal changes on Mars; mass $6.44 \cdot 10^{26}$ g; acceleration of gravity 3.72 m/s^2; 2nd cosmic (parabolic) velocity 5.0 km/s. Mars has an atmosphere consisting mainly of nitrogen and carbon dioxide. The amount of water vapour corresponds to 10—20 μ of precipitation.

Atmospheric pressure on the surface is 10—20 mbar. Cloud patterns are observed in the atmosphere, and are particularly pronounced in blue light. The cloudiness is characterized by yearly and seasonal variations and is preferentially localized in the white-capped regions. Yellow clouds, believed to be sand storms, sometimes cover the entire visible surface of Mars.The surface of the planet is divided into light-coloured regions, orange-red "continents", and dark-coloured regions, grey-greenish "seas". In the polar areas, white caps appear during the period from Martian autumn to Martian summer and in the middle of winter spread to regions with a latitude of 50—60°. Spectrograph investigations indicate that the polar caps, most likely, consist of a layer of ice of hoar-frost structure no more than 1 cm thick. Seasonal changes are also observed in the dark-coloured sea regions of Mars. At the perihelion, the maximum temperature for continents close to the equator is 25°C; for the seas it is 8° higher. During the Martian day the temperature changes by 80—100°C, the night temperature being about —70° to —100°C. From the data available, it is possible that primitive forms of vegetation may exist on Mars. Mars has an albedo of 0.15. Areographic maps show the distribution of the continental and sea areas over its entire surface. The accuracy with which the coordinates of a point in the centre of the disc can be determined will be within about ±1.0° of longitude and about ±0.5° of latitude. At the equator, 1° of areographic longitude and latitude is equivalent to 60 km. Mars has 2 satellites, Phobos and Deimos.

The first spacecraft launched in the direction of Mars was the Soviet automatic interplanetary station *Mars-1*, sent into space on November 1, 1962. From the photographs taken by *Mariner-4* (1965) at a short distance from Mars (12,000—17,000 km), the details of the relief having a size from tens to hundreds of km are similar to those on the lunar surface (craters and circular mountain formations). No signs were detected of "canals", believed to exist by some observers in the past because of the sharp straight lines seen on the surface. These are found in relatively small areas on the photographs.

MARS-1. Name of the Soviet automatic interplanetary station launched in the direction of Mars on November 1, 1962, with the missions of space exploration, proving radio communication on interplanetary distances, and

Maser amplifier



photographing Mars. This station weighed 893.5 kg and carried a set of scientific instruments. *Mars-1* was on communication with the Earth 61 times, transmitting a large amount of scientific information. Communication remained possible up to a distance of 106 million km. Closest approach to Mars, according to the calculated trajectory of the spacecraft, occurred on June 19, 1963, following which the spacecraft went onto a heliocentric orbit with a perihelion of $148 \cdot 10^6$ km and aphelion of $250 \cdot 10^6$ km.

Automatic interplanetary station *Mars-1*. *1*—vernier rocket engine; *2*—magnetometer probe; *3*—high-gain antenna; *4*—temperature control system radiator; *5*—semi-directional antenna; *6*—solar panel; *7*—omni-directional antenna; *8*—orbital compartment.

MASER AMPLIFIER. Am amplifier of electromagnetic oscillations ensuring the gain at the expense of energy transmission from pre-excited atoms (molecules) of a substance to electromagnetic oscillations passing through this substance. Used more often as an exciter is the ruby crystal placed in resonator and cooled in liquid helium. An advantageous feature of maser amplifier is its extremely low level of noises (noise temperature is 7—10°K) and hence, the high sensitivity. In radio receivers of space communication systems use is made of paramagnetic maser amplifiers with a gain of 20—30 dB; the retuning of radio frequency is realized by change of external dc magnetic field. The excitation of atoms (molecules) of the working substance is performed by pumping the resonator with an energy of certain oscillations at higher frequency, e.g., UHF.

MATING DOLLY. An assembly transporter used for carrying the launch vehicle subassemblies from the vehicle assembly building to the assembly site and for mating the subassemblies. A set of mating dollies is provided for assembling a launch vehicle.

MAXIMUM PERMISSIBLE CONCENTRATION (MPC). The maximum, hygienically permissible content of noxious contaminants liberated by a spaceship crew and equipment in the atmosphere of a cabin. The MPC is expressed in volumetric per cent or weight units per volume unit. For example, the MPC of carbon monoxide is 0.02 g/m^3 (see TOXICITY OF COMPONENTS).

McDIVITT, James A. (born 1929, Chicago, Ill.). US astronaut, US Air Force colonel. Graduated from the University of Michigan in 1959, from the Air Force Experimental Test Pilot School in 1960, and from the Air Force Aerospace Research Pilot School in 1961. He was an experimental test pilot at the Edwards Air Force Base. Joined the NASA group of astronauts in 1962. Made an orbital flight as command pilot of the *Gemini-4*

spaceship (together with E. White) on June 3, 1965, circling the Earth 62 times in 98 h and covering a distance of ~2,700,000 km. Made a 10-day space flight beginning on March 3, 1969, as command pilot of the *Apollo-9* satellite-spaceship with D. Scott and R. Schweickart on board, making 151 orbits (6,300,000 km) round the Earth. A complex programme including debugging of the *Lunar Excursion Module* and varied scientific investigations was carried out during the flight.

Medical data management system

MEASURING INSTRUMENTS of fuelling systems. Intended for measuring and checking various parameters during the fuelling of the launch vehicle. The instruments measure and record the following parameters: pressure in hydraulic manifolds, in the pneumatic system controlling the hydraulic actuators, and in the ullage of the propellant reservoir; vacuum in the heat insulation of the cryogenic propellant storage reservoir; pressure in the cylinder batteries of the RECEIVER ROOM; pressure in the pneumatic system and space-borne cylinders of the launch vehicle; temperature, consumption, and level of the propellant; rpm, voltage and current of the pumping plant drive electric motors; positions of hydraulic system shut-off fittings; presence of liquid in fuelling lines, etc. Pressure in the fuelling systems is measured by pressure gauges, pressure-vacuum gauges or pressure transducers. The sensitive element of the pressure transducers is constituted by an elastic membrane; the electric converters being potentiometer or induction type. Remote measurement of temperature is accomplished by means of thermocouples and thermistors, or, rarely, gas or liquid ampoules in which pressure or volume varies with the ambient temperature. The fuel consumption is measured by means of orifices or flowmeters. The fuel level is measured by level gauges of the inductance or capacitance type, or by ultrasonic level detectors. The speeds are measured by electric tachometers.. The positions of the hydraulic shut-off fittings are determined by displacement transducers or limit switches; the former are potentiometric sensors while the latter are circuit-closing devices; operating on the same principle are liquid detectors. The output parameters of all the sensors in the form of electric signals are transmitted to the propellant-loading control system and to the secondary recording and visual indication devices.

MEDICAL DATA MANAGEMENT SYSTEM, automatic. This space-borne system carries out preliminary processing of information on health of crew members and transmits it to the ground stations. The data management system makes it possible to reduce carrying capacity of the telemetry channels by "compression" coding of the information; this is especially important in case of extended space flights. The system evaluates the condition of the crew members and signals danger automatically, without participation of the ground medical personnel; controls the LSS of the spaceship; operates the emergency escape system, etc. Should the spaceship crew include a physician, the data management system can render assistance as a diagnostic computer. A major problem in designing a data management system is the choice of diagnostic algorithms, i.e., an exact assignment of the sequence of operations required to solve a diagnostic problem, including preliminary processing of physiological signals, mathematical operations with complexes of physiological data, the processes of compari-

son and coding. The data management system consists of information input units which transform electric signals from sensors and amplifiers into numerical code of the computer (usually electronic), and information output units (dial indicators, shields, coding systems for radio channel, inputs, etc.). In simplest cases, diagnostic problems can be solved with electronic logic computers.

MEDICAL INSTRUMENTATION, space-borne. An important constituent of the physiological monitoring system on board a spaceship. The principal functions of the space-borne medical instrumentation are amplification and transformation of signals coming from sensors and electrodes fixed to the spacemen's bodies, introduction of the medical information into the telemetry system for data transmission to the Earth and into the space-borne computer or memory unit. The space-borne instrumentation differs from ground-type units by smaller dimensions, weight, and power consumption. This instrumentation uses transistors, the latest radiotechnical materials and elements. The space-borne medical instrumentation can register a number of physiological functions. A specific feature of this instrumentation is its high reliability in long-term operation and under the action of extreme environmental factors (vibration, accelerations, etc.). The space-borne medical instrumentation is put into and out of operation by a programming device on board the spaceship or on commands from the ground. Some types of the instrumentation may be manually operated in flight. Thus, on board the *Voskhod-1* spaceship an amplification unit for programmed physiological examination was installed: this unit was operated by the physician-cosmonaut B. B. Yegorov. Further development of space-borne medical instrumentation involves micro-miniaturization, designing of module units, increasing of the sensitivity, and improving resistance of the amplification channel against interferences.

MEDICAL MONITORING in space flight. Observation of the health status of spaceship crew members. In space flight, a relatively small number of physiological functions are recorded by permanent sensors on the spaceman's body. It is highly important that the functions selected yield the greatest amount of information for prompt evaluation of the spaceman's condition. Maximum radio-noise protection of the records is necessary to ensure precise information not only during rest periods of the spaceman, but also in time of his activity involving movement and muscular effort. Soviet cosmonauts were observed in flight by means of electro-cardiography, seismocardiography and pneumography; the respective sensors were fixed to their bodies with the help of a chest girdle. Physiological functions are usually radio-telemeasured; data obtained by TV and radio communication are also used. After launching the spaceship, a system of ground telemetry stations (each with a medical group) goes into operation. All data on the spacemen's condition are concentrated at the flight control centre; here the data are compared with the results of ground tests and training reports. Highly important during the flights of the *Vostok* and *Voskhod* spaceships was continuous transmission of the spacemen's pulse by means of the *Signal* transmitter. Mathematical methods of heart rhythm evaluation have been developed that permit judging about the spaceman's status by the pulse

rate alone. The presence of a physician on board the ship does not essentially change the general principles of medical observation, but reliability is increased. The physician can quickly detect any deterioration in the crew members condition and render aid; nevertheless, he needs ground medical monitoring. In future, medical observation will be done by on-board computers.

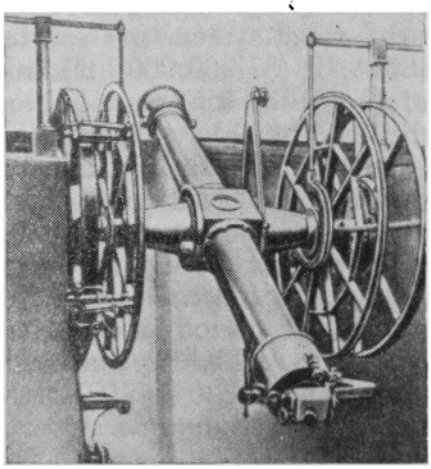
MELANGE. A mixture of nitric and sulphuric acids that was used as an oxidizer in liquid propellants for rocket engines.

MEMBRANE UNIT. A separating device. A membrane in a special casing built into a pipe serves to completely separate the ground propellant-loading line from the launch vehicle propellant tanks. It is used when an empty launch vehicle is long kept on the launch pad with filling connectors mated. The membrane unit protects the launch vehicle tanks against the effect of aggressive propellant vapours. As propellant loading begins, the membrane is ruptured by the pressure in the loading line or by cutting devices.

MERCURY, PLANET. The principal planet of the solar system nearest to the Sun. Its mean distance from the Sun is 0.387 A.U. (57,900,000 km), its orbit has an eccentricity of 0.206, a perihelion of 46 million km, an aphelion of 70 million km and is inclined 7°0′ to the ecliptic. The sidereal period of revolution amounts to 87 days 23 h 16 min. Mercury is close in shape to a sphere with a radius of 2420 km. An analysis of a sufficient number of drawings of the mercurian surface reveals that the observed recurrences may be due to periods of rotation equal to 50.1; 58.4; 70.2; or 88 days. Radar measurements yield the value of sidereal period of rotation amounting to 59 ± 7 days. Rotation of Mercury shall be stable if its period is equal to 2/3 of the period of orbital revolution, i.e., 58.65 days, which is the most probable value; then solar day shall have a duration of 220 ± 40 Earth solar days. It is believed that the equatorial plane of Mercury has a very little inclination to the ecliptic. Other data of importance are: mass $3.33 \cdot 10^{26}$ g; acceleration of gravity on the surface 3.8 m/s^2; 2nd cosmic (parabolic) velocity 4.3 km/s. Indication of presence of carbon dioxide gas has been detected in the mercurian atmosphere whose thickness is 0.003 of that of the Earth. Atmospheric pressure at the surface equals 1—3 mbar. During perihelion passage, the temperature in the middle of the sun-heated hemisphere is 420°C, during aphelion passage, 300°C. On the dark hemisphere the mean temperature is —70°C. The mean density of Mercury is 5.62 g/cm^3. This figure makes it permissible to assume that the planet contains heavy elements, including the radioactive ones, in a proportion twice that of the Earth. Consequently, the core of Mercury has a high temperature, in all probability accompanied by volcanic processes producing, as a result, a markedly mountainous relief. Presumably, an important role in shaping of the relief can be attributed to meteoritic accumulations. The albedo of Mercury is 0.06, its surface is red-brown.

Hermesographic maps show dark and light areas amounting to about 5/8 of the total surface of the planet. 1° of hermesographic longitude and latitude at the equator is equivalent to 40 km. The brightest celestial bodies in the Mercurian sky (apart from the Sun) are Venus (stellar magnitude —8) and Earth (stellar magnitude —5).

MERCURY, SPACESHIP. A series of early American single-seater spaceships intended for orbital flights; also the name of the program (Project *Mercury*) according to which they were developed and orbited. The *Mercury* capsule weighed about 1.4 t, was 2.9 m long, and had the shape of a truncated cone with a base diameter of 1.8 m. It was designed for sea landing only. The astronaut wearing a space suit was seated in the capsule. With the aid of the *Mercury* capsule, the first American manned flights in space were accomplished, initially on a ballistic (suborbital) trajectory, and then on full round-the-Earth orbits having a perigee of about 160 km and an apogee up to 285 km. It was in a *Mercury* spaceship named *Friendship-7* that J. H. Glenn completed the US first orbital flight on February 20, 1962. ten months after the flight of Y. A. Gagarin. M. S. Carpenter completed the 2nd flight in the *Mercury* spaceship named *Aurora-7* on May 24, 1962. Both flights lasted for about 5 h (3 orbits). The 3rd flight was made by W. M. Schirra in the *Mercury* spaceship *Sigma-7*. It lasted 9 h. The 4th flight of a *Mercury* spaceship, *Faith-7*, was made on May 15, 1963, with the astronaut L. G. Cooper on board. It continued for 34.3 h. After 1963 these spaceships made no flights.



Meridian circle.

MERIDIAN CIRCLE. A TELESCOPE pivoted on special bearings to rotate only in the plane of a CELESTIAL MERIDIAN around a horizontal axis. It is used to determine the moment of passage of stars, the Sun, the Moon, or planets through the meridian, and their zenith distances at this moment.

MESHCHERSKY, Ivan Vsevolodovich (1859—1935). Outstanding Soviet scientist in the field of mechanics. Graduated from the St. Petersburg University in 1882 and was selected for professorship training there. Beginning with 1902, was a professor of Petersburg (Leningrad) Polytechnical Institute. His most significant papers are devoted to the mechanics of bodies with a variable mass. In his works, *Dinamika tochki peremennoi massy* (*Dynamics of a Point with a Variable Mass*, 1897) and *Uravneniya dvizheniya tochki peremennoi massy v obshchem sluchaye* (*Equations of the Motion of a Point with a Variable Mass in the General Case*, 1904), he presented a general theory of the motion of a point with a variable mass, first for the separation (or joining) of particles and then

for the simultaneous separation and joining of particles. The principal equations of rocket dynamics are expounded in these works. Meshchersky's paper *Zadacha iz dinamiki peremennych mass* (*A Problem in Dynamics of Variable Masses*, 1918) is devoted to the motion of a system of points with variable masses. An outstanding teacher, Meshchersky radically changed the teaching of the course in theoretical mechanics, bringing it closer to the courses in applied mechanics. Compiled by Meshchersky was *Sbornik zadach, otnosyashchikhsya k kursu teoreticheskoi mekhaniki* (*A Collection of Problems in Theoretical Mechanics*, parts 1—2, 1909—1911; 31st ed., 1967). A crater on the far side of the Moon has been given his name.

MESOPAUSE. An intermediate region of the atmosphere with minimum temperature at a height of about 85 km. Mesopause is distinctly observed only in summer; winter measurements show nearly constant temperature between approx. 60 and 90 km. The nature of mesopause is still unclear.

MESOPEAK (stratopause). A region of the atmosphere with maximum temperature at altitudes of the order of 50—60 km. Below that level the intensity of the Sun's UV radiation in the 1800—3400 Å region of the spectrum markedly diminishes due to absorption by the ozone molecules, while above that level the concentration of absorbing ozone molecules and water vapour rapidly declines. Thus, the maximum influx of heat occurs at altitudes of the order of 50—60 km and this causes the appearance of a temperature maximum. Ozone and water vapour concentration is rather variable above the mesopeak, hence at altitudes above 50 km a temperature drop is not always observed. Usually the mesopeak is distinctly expressed in the summer; in the winter it may dissapear.

MESOSPHERE. The region of the atmosphere between the mesopeak and the mesopause, at altitudes of about 50—90 km. Energy in the mesosphere is mainly transferred by radiant heat exchange, the basic processes being the absorption of solar radiation by ozone (for wavelengths shorter than 3000 Å), by water vapour and carbon dioxide, and the scattering of UV radiation by oxygen molecules. Complex photochemical processes occur in the mesosphere, in which chemically active components of the atmosphere, such as free radicals, vibratory excited molecules, etc., participate. These processes produce an air glow consisting mainly of the glow of the hydroxyl radical (in the visible and IR spectra), oxygen molecules in the Hertzberg bands (in the UV spectrum), the continuum (in the visible spectrum), and a number of other emissions. By analyzing this glow, spectroscopic measurements of temperature in the mesosphere can be made regularly from ground-based stations. On the other hand, it is assumed that heat removal due to IR emission of the hydroxyl radical and carbon dioxide plays a part in the heat balance in the upper part of the mesosphere. The structural parameters (density, temperature) of the mesosphere are measured in detail by instruments borne by meteorological probes. Seasonal variations of temperature have been revealed in the mesosphere; the development of large-scale vortices, prolongation of phenomena originating in the lower atmosphere, has been observed in this region. The structural characteristics of the mesosphere must be studied, in particular, for calculation of the re-entry corridor, i.e., the trajectory of spacecraft deceleration during re-entry.

METABOLIC WATER. Water formed in human organism as a result of oxidation of various substances. Complete oxidation of 100 g of fats, carbohydrates or proteins yields 107, 55 or 41 g of water respectively. On the average each 10 kcal of food should yield about 1 g of water. When calculating the water balance for a spaceman, metaholic water must be taken into consideration, and the quantity of liquid excreted should exceed the amount of liquid entering the organism by the value of metabolic water.

METAGALAXY. The inclusive system of all stellar systems (galaxies). Our GALAXY is one of the systems in the metagalaxy.

METAL-CONTAINING PROPELLANT. A propellant for rocket engines, which contains powders of light metals: lithium, beryllium, magnesium, aluminium, etc., or their chemical compounds (hydrides, metallo-organic compounds). In a number of cases, metals and their compounds increase the specific impulse. Boron-containing propellants also possess this advantage. Use is made of aluminized solid propellants. Triethyl aluminium is employed as liquid igniter propellant for chemical ignition in engines in which LOX is used as the oxidizer. Experimental work is being carried out with a view of using boron- and beryllium-containing rocket propellants.

METASTABLE PROPELLANT. A hypothetical propellant containing free atoms (see MONATOMIC PROPELLANT) and more complex radicals capable of recombination with large energy release. Hypothetically possible are also propellants containing excited atoms and molecules whose electrons are on the higher energy levels, and this energy of excitation could, theoretically, be used in rocket engines. Metastable components of rocket propellants (oxidizer, fuel) are theoretically conceivable; in this case the energy of recombination or excitation is combined with the energy of oxidation. Attempts to obtain metastable propellants have been unsuccessful.

METEOR. A brief luminosity produced by meteoroids, i.e., small solid bodies, entering the Earth's atmosphere at a speed of 12—73 km/s. The solid bodies moving in INTERPLANETARY MEDIUM are also sometimes referred to as meteors. On entering the extremely rarified upper atmosphere, meteoric particles become heated by collisions with atmospheric molecules and, at an altitude of 130—80 km, vaporize intensively. Particles larger than 1 cm penetrate below that level and produce especially bright meteors called BOLIDES. Collisions of the vaporized molecules with one another and with the molecules of air result in dissociation, excitation and ionization of the atoms formed; this brings about a luminescence. The ionized trails of the meteors reflect radio waves. Dust particles $\leqslant 10^{-3}$ cm in size are braked by the atmosphere before their vaporization and luminosity begins; along with the remnants of larger particles, they slowly settle down on the surface of the Earth. Special instruments in geophysical rockets at altitudes below 120 km record the impacts of these particles and, beyond the atmosphere, the impacts of dust moving at cosmic speeds. In the Earth's atmosphere, an average of 10 meteors/h are visible to the naked eye; they are produced by bodies a fraction of mm or larger in size. The number of meteors increases several times when the Earth encounters meteoric streams. The average daily fallout of meteoric matter on the Earth is several thou. t.

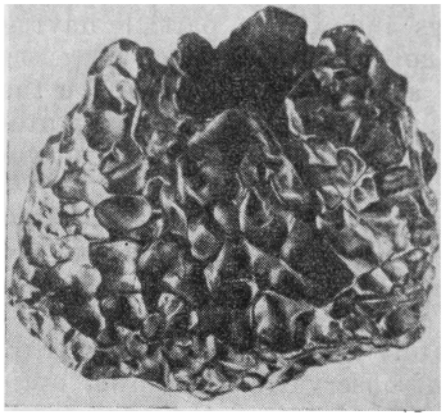
METEORIC DANGER. The danger of spacecraft collision with solid particles of interplanetary medium. It depends on the velocity of the collision and the mass of the particle. Particles with a mass of several tens of mg or over can pierce the skin of a spacecraft, while encounters with smaller particles cause gradual erosion of the spacecraft shell and the optical, light-sensitive and other instruments with unprotected surfaces. The collisional frequency depends on the mass of the particles and the trajectory of the spacecraft. A spacecraft, moving in a heliocentric orbit near the Earth's orbit and having a surface area of 100 m^2, will collide on the average with a particle having a mass of 10^{-3} g once in several days and with a particle having a mass of 10^{-8} g, once in several seconds. The collisional frequency increases for spacecraft moving in a geocentric orbit at a low altitude above the Earth's surface (in the Earth's dust cloud). Meteoric danger faces automatic and manned stations on celestial bodies without protective atmosphere.

METEORIC EROSION. The wearing of the spacecraft shell under the action of small meteoric particles (cosmic dust). At a collision velocity of tens of km/s each meteoric particle, on bursting, breaks up and evaporates a quantity of matter that considerably exceeds its own mass. The magnitude of meteoric erosion has been estimated approximately to be 10^{-4}—10^{-6} cm/year. Meteoric erosion affects mostly the surfaces of observation windows, optical instruments, solar batteries, and radiation surfaces of the spacecraft, thus causing alterations of the optical properties.

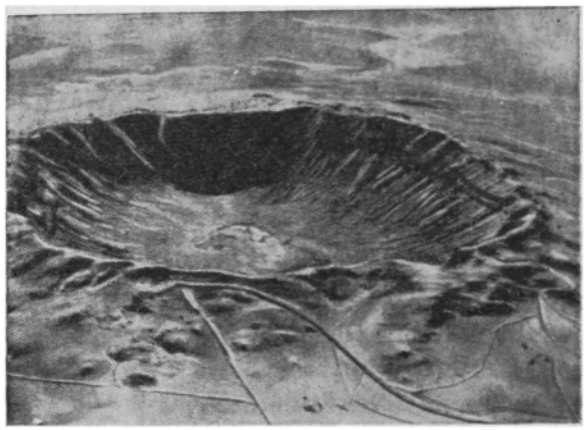
METEORIC PENETRATION PROTECTION. Means to reduce the probability of puncture of the spaceship's air-tight skin by meteoric particles (see METEORIC DANGER). This protection becomes necessary for flights lasting for several months, for large-size spacecraft, and for spacecraft that are likely to encounter METEOR STREAMS. The most effective means of meteor protection in long-term flight is to shield the skin of the air-tight compartment with a meteor bumper, i.e., thin metal sheets placed apart of the skin. When a meteoric particle strikes the bumper, it is disintegrated and loses its kinetic energy. Other means of meteor protection include: subdividing the cabin into separate chambers, sectionalizing the hydraulic radiators (e.g., of a nuclear power plant), and incorporating a puncture detection and healing system. No special meteor protection is provided on the up-to-date spacecraft sent into circumterrestrial orbits for up to several weeks, as the probability of a meteoroid puncture is low.

METEORITES. Iron and stony bodies that have fallen on Earth from outer space as the remnants of meteoric bodies (see METEOR and BOLIDES). The heaviest known individual iron meteorite, found in Hoba, Southwest Africa, weighs 60 t. The Sikhote-Alin iron meteorite shower which fell in the Far East of the USSR in 1947 consisted of many thousands of fragments totalling over 23 t. Falls of meteorites weighing from a fraction of a gram to several kg are frequent. The main characteristics of meteorites are a fusion crust and the typical pittings known as regmaglipts, or thumb-prints, that are formed on the surface by the air flow. Iron and stony meteorites both have magnetic properties. Although no less than a thousand meteorites fall each year, most of them are not found. The meteorites of some 1800 falls

have been collected by the museums of the world. The USSR has meteorites from 135 falls. Giant meteorites with a mass of several thou. tons fall once in several hundred years. The atmosphere is incapable of fully decelerating a meteorite of this size and it hits the ground at a speed of several km/s. This is accompanied by an explosion due to transition of kinetic energy into heat energy. A crater is thus formed at the spot where the meteorite strikes the ground and only small fragments of the meteorite remain. On the



One of the Sikhote Alin iron meteorites weighing 7.77 kg (seen on the surface are regmaglypts).

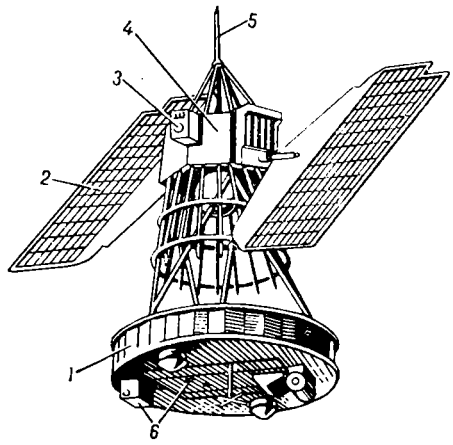


Arizona (USA) meteorite crater (Barringer crater). It is 1207 m in diameter and 174 m in depth.

Earth there are no more than about 20 proven meteorite craters with diameters ranging from a few tens of m to tens of km. The largest of the group of meteorite craters found on Sarema Island, Estonian SSR, is 110 m in dia. Meteorites are subdivided into (1) iron meteorites, composed mainly of iron, nickel and cobalt, and (2) stony meteorites, composed of silicon, oxygen, magnesium, sulphur, iron, etc. The major types are: (a) iron-stony and (b) stony-iron. Mention should also be made of the group of glassy meteorites known as tektites; these occupy an intermediate place between terrestrial rocks and meteorites. Elements unknown on the Earth have not been discovered in meteorites but they do contain small quantities of minerals unknown on Earth (indication that they were formed in conditions differing from those of the Earth's crust). Meteorites contain radioactive chemical elements whose isotopes are used to study the intensity and variation of cosmic rays in interplanetary space and the space age of the meteorites (lifetime in interplanetary space as independent bodies after breakup of the parent asteroid) is determined. The space age of meteorites ranges from several tens to hundreds of millions of years, while the age of the matter of which they are composed is approx. 4,500,000,000 years. The study of meteorites contributes towards solving the problem of the origin of the solar system and its evolution, investigation of the motion of solid bodies through the atmosphere surrounding the Earth, and the conditions and degree of their disintegration. The science of meteorites is known as meteoritics.

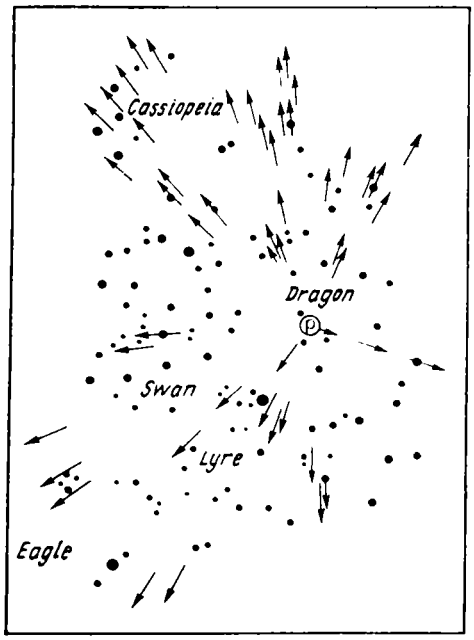
METEOROLOGICAL CENTRE. An organization gathering, processing and distributing meteorological information. At present 3 world meteorological centres exist: in the USSR (Moscow), the USA (Washington) and Australia (Melbourne). Regional and national meteorological centres form a world-wide network.

METEOROLOGICAL SATELLITE. An Earth satellite equipped to observe the cloud patterns in the Earth's atmosphere and measure the heat radiation of the Earth for weather forcasting purposes. The TV pictures obtained along the route of the satellite are generally stored in the space-borne memory unit (magnetic tape recorder) and then relayed to Earth when the satellite comes within direct line-of-sight communication with the ground receiving stations. The radiation of different areas of the Earth is detected by special spaceborne equipment. Meteorological satellites, as used at present,



American meteorological satellite *Nimbus*.
1—scientific instrument container; *2*—solar cells; *3*—orientation system sensors; *4*—attitude control system container; *5*—antenna; *6*—TV cameras and radiometers.

orbit mainly at heights from 500 to 1200 km. This permits them to have coverage bands of up to 1000 km and wider. Of great interest for meteorology is a global picture of the cloud distribution round the Earth. Experiments of this type were conducted with the aid of the Soviet *Molniya-1* satellite from heights reaching 30—40 thou. km. Besides furnishing information for weather forecasting, meteorological satellites give highly important information on the development and movements of typhoons. Among the satellites sent up on meteorological missions are several of the Soviet *Cosmos* series (e.g., *Cosmos-122*, *Cosmos-144*, *Cosmos-156*), the American satellites of the *Tiros* and *Nimbus* series, etc.



Radiant point of the Draconid meteor stream.

METEOR STREAM. The group (swarm) of meteoric particles expelled by disintegration of a comet and moving in orbits approximating that of the comet. Also known as a meteor stream is the group of METEORS comprised of

the material of one swarm entering the Earth's atmosphere. Meteor streams are observable on definite days each year. When the Earth encounters a meteor stream, meteor bodies with practically parallel trajectories are visible, although when traced backward they appear to radiate from a small area in the celestial sphere known as the radiant. The principal meteor streams producing several tens of meteors per hour are named after the constellation in which their radiant is located. The Earth encounters highly condensed meteor streams, so-called meteor showers, only a few times in a hundred years.

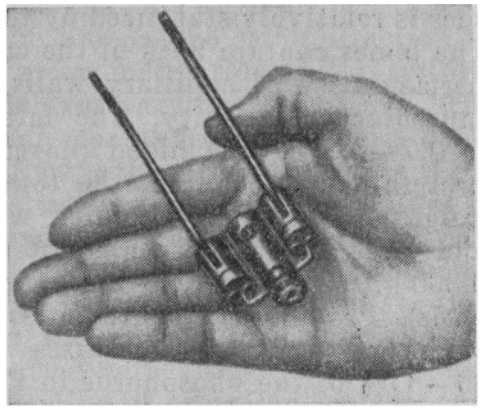
METEOR SYSTEM. A Soviet space meteorological system incorporating weather satellites of the *Cosmos* and *Meteor* series, posts for reception, processing and dissemination of meteorological information, and a space-borne equipment control service. The system is designed for regular collection of meteorological data so that the weather service can operate efficiently and for purposes of research. The system began to function on April 27, 1967, when the *Cosmos-154* and *Cosmos-156* satellites were launched. The orbits selected ensure weather observation in each area with a period of ~6 h. The TV and IR equipment of the satellites takes pictures of the cloud canopy, the snow cover and ice layer in both the day and night areas of the Earth, while actinometric instruments measure the radiation emitted and reflected by the Earth and the atmosphere. Two satellites daily obtain meteorological information from one half the surface of the globe. The data transmitted by these satellites are received by a network of ground-based posts equipped for recording and processing the information and transmitting it via direct channels to the Hydrometeorological Centre of the USSR; automatic data processing takes ~1.5 h.

The data obtained by the *Meteor* system greatly improve the reliability of weather forecasts, make it possible to detect powerful cyclones and typhoons in the oceans, to select the best routes for merchant and fishing vessels, to determine the boundaries of the ice sheet in Arctic regions and particularly along the Northern Sea Route, to obtain information on areas of enduring precipitation (for agriculture), etc. The *Meteor* system also provides data important in the development of a theory of circulation of the atmosphere as a whole and creation of reliable methods of long-range weather forecasting.

METHYL ALCOHOL, CH_3OH. A fuel for liquid-propellant engines. A colourless high-boiling liquid with a faint alcoholic odour; density 0.792 g/cm^3 at 20°C; m.p.—97.9°; b.p. 64.7°C. Poisonous, stable, noncorrosive. Its performance is analogous to that of ethyl alcohol. Its mixtures with hydrazine hydrate were used in combination with hydrogen peroxide, mixtures with other alcohols were burnt with LOX. At present more effective fuels are used.

MICRO-ORGANISMS. The simplest vegetable and animal organisms. They may be used in BIOCOMPLEX of spaceships as active participants in the RECYCLING OF SUBSTANCES in the LSS, for regeneration of air, water, and vegetable foods, MINERALIZATION of biological wastes, etc. Micro-organisms include algae, bacteria, micro-organisms of active sludge, yeasts, some fungi, etc.

MICROROCKET ENGINE. A rocket engine capable of thrust of several kg and lower (up to a fraction of gram). It is used primarily for stabilisation and attitude control, or as a PERSONAL ROCKET ENGINE. A microrocket engine is restartable and can be fired many times.



Microrocket engine for spacecraft attitude control system (USA). Burning methane and oxygen, it develops a thrust of 0.2 to 45 gramms

MIDCOURSE CORRECTION ROCKET ENGINE. A rocket engine that is started in flight to correct the direction and magnitude of the spacecraft velocity. Such engines are usually restartable and burn a storable liquid propellant.

MILITARY EARTH SATELLITE. The USA launch satellites designed for all kinds of reconnaissance from space, destroying other satellites or ground targets, and similar missions. The military satellites include the American *Discoverer* and *Samos* satellites carrying photo and other reconnaissance equipment. No data on their characteristics are available. The launching of space vehicles with nuclear warheads into near-Earth orbits is prohibited by international agreements (see SPACE LAW).

MILKY WAY. Milliards of stars forming on the sky a faint (milk-coloured) irregularly outlined band of light of varying width. Its centre-line is located approximately on the great circle on the CELESTIAL SPHERE, inclined to the plane of the CELESTIAL EQUATOR at an angle of about 63°. The poles of the circle, at inclinations of +27.4° and —27.4°, may be called the poles of the Milky Way. See also GALAXY.

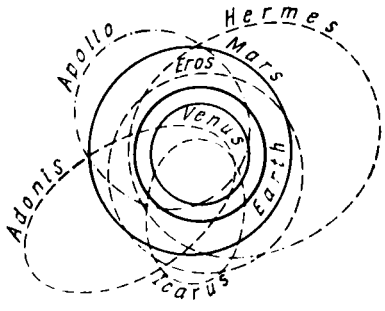
MINERALIZATION. Decomposition of organic and inorganic compounds contained in human and other biological (see BIOCOMPLEX) wastes. Its purpose is to obtain chemical substances and elements necessary for material circulation in a spaceship. The products obtained by mineralization of organic compounds are CO, CO_2, NH_3, S_xO_y, N_xO_y, N_2, H_2O, and by mineralization of inorganic compounds, various metal oxides and mineral salts. The products of mineralization may be contained in the solid, liquid and gaseous phases. Mineralization is effected by physico-chemical and biological methods. Physico-chemical methods are based on the use of high temperatures, catalytic reactions, increased temperatures and pressures (see WET OXIDATION). Biological methods are based on the use of active sludge and algo-bacterial communities consisting of various micro-organisms and algae.

MINERAL METABOLISM. Consumption and excretion of mineral salts by the organism as a part of general change of substances between the organism and the environment. Mineral metabolism is the basis for a number of processes vitally important to the spaceman, such as maintenance of water balance and distribution, maintenance of osmotic pressure and alkali-acid equilibrium, etc. The concentration of mineral salts in body liquids and tis-

sues is relatively stabilized by the activity of certain regulation mechanisms. The bones contain 99% of the calcium in the organism, calcium ions reduce permeability of capillary walls and cell membranes and diminish neuromuscular excitability. The minimum daily calcium requirement of man is 0.7—0.8 g. The blood plasma contains 50—60% ionized and 40—50% protein-bound calcium, the total calcium content being 8.5—12 mg% (by weight). Calcium is excreted with bile, digestive secretions, urine, feces, and sweat. The daily amount of calcium excreted with urine is 0.140—0.300 g; with sweat, 1—8 mg per 100 mg; with feces, 8—10% (on dry weight basis). Prolonged weightlessness disturbs calcium metabolism and the calcium loss by bones increases (see DECALCIFICATION). The bones contain 80—85% of the phosphorus in the organism; in the form of phosphate radicals (PO_4) it is present in both organic and inorganic compounds. Inorganic phosphorus is of primary clinical importance; its content in blood plasma is 3—4 mg% (by weight). The daily phosphorus requirement is 1.5—2 g. Phosphorus is excreted with urine and feces: in urine it varies from 0.5 to 3.0 g per 24-hour period, i.e., 60% of the total amount excreted. Sodium, potassium and chlorine maintain a normal water balance, osmotic and acid-alkali equilibrium. Sodium and chlorine are considered intercellular elements, and potassium intracellular. Man's daily requirements are 4—6 g sodium, 2—3 g potassium and 2—4 g chlorine. In normal conditions the amounts of potassium, sodium and chlorine excreted with urine, sweat and feces equal the amounts that enter the organism within the same period of time.

In space flight conditions, many factors cause changes in the organism's electrolytic balance. Re-distribution of the organism's liquids may have grave consequences under conditions of high accelerations and weightlessness, which, in turn, may have a reflectory effect on the hormonal system and bring about a disturbance of the water and electrolytic balance.

MINOR PLANETS (asteroids, planetoids). The celestial bodies circling the Sun in elliptical orbits laying mostly between those of Mars and Jupiter (see SOLAR SYSTEM). The largest minor planets have diameters of several hundred km, while the smallest ones are less than 1 km in dia. The first minor planet, Ceres, was discovered in 1801; Pallas, in 1802; Juno, in 1804; and Vesta, in 1807. Since 1847 minor planets have been discovered every year; by 1966, out of 60,000 minor planets accessible to observation, 1685 had been listed in catalogues. The diameters of minor planets are:



Orbits of several minor planets.

Ceres, 768 km; Pallas, 489 km; Juno, 193 km; Vesta, 385 km; the dimensions of the smaller minor planets are inferred from their STELLAR MAGNITUDES with a probable error of 30—40%. The density of minor planets is about 3.5 g/cm³. The force of gravity at the surface of Ceres is about 1/30 of the

Earth's; it is even less on other minor planets and this explains the absence of atmospheres. The minor planets circle the Sun in the same direction as the major planets (mean eccentricity 0.15, mean inclination to the ecliptic plane 9.7°); periods of revolution about their axes vary from 2 to 9 h. The mean distance of 97% of the registered minor planets from the Sun is 2.2—3.6 A.U. Minor planets come quite near the Earth; thus, the nearest approach of Eros is 22 million km, that of Icarus, 6.5 million km (1968), and that of Hermes is Moon's distance (1937). The irregular (chipped) shape of minor planets, the existence of major planets with similar orbital elements and the connection of minor planets with METEORS suggest that they are fragments of one large planet, while the variety of orbits may be the result of later collisions and fragmentation (other theories also exist).

MIXING. The injection, atomization and blending of propellant components in the combustion chamber or gas generator of a liquid-propellant engine in order to ensure a stable and complete combustion of the propellant. Mixing is effected by a MIXING SYSTEM which ensures a sufficiently homogeneous mixture of propellant components with a pre-set distribution of the concentration and flow intensity in the reaction chamber, and the required quality of atomization. Mixing is a complex process because a number of factors facilitating a high degree of propellant combustion are at the same time conducive to high-frequency instability of the combustion process. That is why ensuring a high value of specific impulse and stable operation of a rocket engine is an important and difficult problem in the creation of an engine. It usually determines the expenditures and time necessary to complete the entire project.

MIXING SYSTEM. A device for MIXING. Depending on the design of mixing elements, the mixing systems are classified as INJECTOR HEADS, SPRAY INJECTORS, SPLIT INJECTORS, burner-cup injectors, etc. It is the mixing system design that mainly determines the perfection of an engine, i.e., complete combustion, stability of the combustion process (absence of highly developed pressure oscillations), homogeneity and stability of the gas temperature pattern, etc., which is important to ensure the cooling of elements with high thermal stresses of the combustion chamber and the gas generator. The mixing system is the most important unit of the combustion chamber of a liquid propellant engine. It usually accounts for most of the time and money spent on the development of a reliable design of the combustion chamber and gas generator with specified characteristics.

MIXTURE RATIO. The ratio of weight or volume flow rate of the oxidizer to the corresponding flow rate of the fuel. Usually, both by weight and by volume, it is greater than 1.

MODEL ATMOSPHERES. The theoretical models wherein (on the basis of observation data) the distribution of density, temperature, and chemical composition of a planetary atmosphere is given. The models are of great importance for space flight as they make it possible to select, at least approximately, the landing mode and the deceleration means for those spacecraft which are to be landed onto a planet.

MODULATION. The process of varying continuous electrical or electromagnetic HF oscillations in step with lower (modulating) frequencies of the

message by means of a modulator. Amplitude, frequency and phase modulation are the basic types of modulation of electrical HF oscillations; polarization modulation is possible for electromagnetic oscillations. Simple as well as complex modulations combining some of the basic types (e.g., pulse-code, frequency-phase, pulse-duration modulation, etc.) are employed in space communication practice.

MOISTURE-CONTENT INDICATOR. An instrument that serves for determining the relative humidity of a gas, e.g., air or nitrogen, used at the space centre. At a certain low temperature of air, the water vapours present in the gas are liable to attain their point of saturation (dew point). At a further, even slight, drop of the temperature, the water vapour becomes supersaturated and the excess moisture falls out as dew.

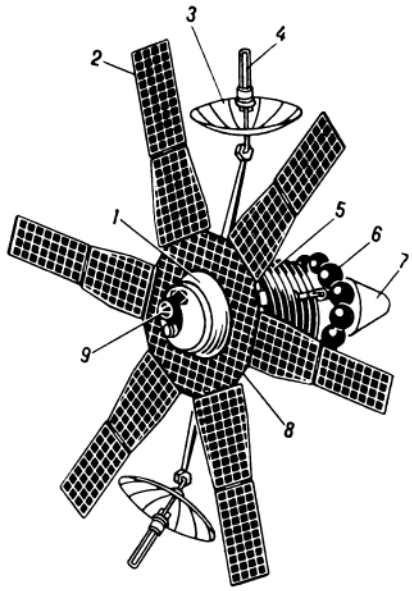
Within the instrument a jet of gas is directed onto a mirror whose temperature is gradually lowered. At the moment of dew dropout—fogging of the mirror—the indicating instrument of the mirror thermocouple indicates the dew point of the gas. In cases when continuous or periodic measurement of the compressed gas dew point is to prove that it does not exceed a certain pre-set value, use is made of an automatic photo-electronic moisture-content indicator wherein the temperature of the mirror is kept automatically at the required dew point level. The moment of dew dropout is recorded by the photo-electronic circuit of the instrument. The moisture-content should be measured in order to make sure that the dew point of the compressed air supplied to pneumatic control systems is not above specified value, otherwise the moisture is liable to condense and freeze when the air is throttled in valves, pressure reducers and narrow sections, which can impair the operation of the pneumatic control system.

MOISTURE SEPARATOR. A mechanical device for separation of moisture from the cabin air and collection of condensate after the air has been cooled in the heat exchanger of the spaceships temperature control system. The moisture separator of the *Mercury* spaceship is a polymer sponge from which the condensate is automatically squeezed at regular intervals. The *Apollo* spaceship has a centrifugal moisture separator.

MOLNIYA-1. Name of Soviet communication satellites intended for relaying of TV programs, and long-distance telephone and telegraph communication. These satellites have been used since 1965. They are part of the *Orbita* space system of long-range radio communication. These satellites travel on an elliptical orbit of great eccentricity with an apogee of about 40 thou. km in the Northern hemisphere. With an orbit of such shape (for points located in the USSR and other countries in the Northern hemisphere), communication may be maintained for up to 8—10 h at a time. *Molniya-1* satellites have rocket engines to make CORRECTIONS OF ORBITS in order to alter the hours of available communication time and to synchronize the travel of several satellites moving round the Earth at the same time. The output power (40 W) of the relay transmitter on *Molniya-1* is considerably higher than that on other known communication satellites. The satellite's design provides in-flight orientation of solar batteries towards the Sun and of the parabolic antenna towards the Earth.

The 1st *Molniya-1* satellite which was launched on April 23, 1965, regularly

provided TV and telephone exchange between Moscow and Vladivostok for many months. On October 14, 1965, the 2nd *Molniya-1* satellite was launched for experimental 2-way long-distance TV, telephone, and telegraph communication; the 3rd *Molniya-1* satellite, launched on April 25, 1966, besides serving for communication and TV broadcasting between USSR ground stations, was also used for an exchange of TV programs between the USSR and France, this including colour TV. Since May, 1966, TV



Molniya-1 communication satellite.
1—sealed body; *2*—solar battery; *3*—high-gain antenna; *4*—Earth sensor for antenna orientation; *5*—radiative cooler; *6*—working fluid for minor corrections of flight path; *7*—correction engine; *8*—heater panel; *9*—Sun sensors.

equipment on board the *Molniya-1* satellites yields images of the Earth as seen from altitudes of 30,000—40,000 km, which contain information about cloud pattern in globular scale; a colour photo of the Earth taken from space was produced in 1967. By August 1, 1968, 13 *Molniya-1* satellites have been placed into orbits to provide regular communication and TV broadcasting over the territory of the USSR and other countries.

MONATOMIC PROPELLANT. A hypothetical propellant containing free atoms that, on recombination into molecules in the rocket engine, release large amounts of heat, e.g., atoms of H (monatomic hydrogen), O (monatomic oxygen), N (monatomic nitrogen), etc., constituting free radicals. Recombination of hydrogen atoms, $H + H \rightarrow H_2$, releases 51,300 kcal/kg, the greatest amount of heat of all known chemical reactions. Attempts to develop methods of obtaining stable condensed monatomic propellants or, at least, of introducing them as admixtures of adequate concentrations have not, as yet, been successful.

MONOMETHYL HYDRAZINE, $H_2N—NH(CH_3)$. A liquid fuel for rocket engines. A colourless, fuming (in air), hygroscopic, high-boiling liquid of ammoniacal odour; absorbs oxygen and carbon dioxide from the atmosphere; density 0.875 g/cm^3 at 20°C; m.p. —52.4°C; b.p. 87.6°C. Poisonous, stable at room temperatures in the absence of air. Its thermostability is satisfactory, but at elevated temperatures it decomposes releasing heat and generating hot gaseous products (it can serve as a source of gas generation); explodes on overheating in a closed chamber. Approximately as corrosive as unsymmetrical DIMETHYL HYDRAZINE. It ignites spontaneously with nitric acid, nitrogen tetroxide, and a number of other oxidizers. Occupies a position between those of HYDRAZINE and unsymmetrical dimethyl hydrazine as far as effectiveness and stability are concerned.

Mono-
propellant

MONOPROPELLANT. A rocket propellant, solid or liquid, consisting of a single component or a homogeneous mixture or solution of various components. In the USSR, the GDL since 1931 carried out captive tests of an experimental rocket engine firing a liquid monopropellant consisting of solutions of nitrogen tetroxide in toluene or gasolene.

MONTH. A period of time approximating the time of one revolution of the Moon around the Earth. Known are: (1) the synodic month: the average interval between successive full moons, having a duration of 29.5306 mean solar days; (2) the sidereal (stellar) month: the average period in which the Moon makes one complete revolution around the Earth and returns to its initial position relative to the stars; this month is equal to 27.3217 mean solar days; (3) the nodical month (draconic period): the mean time between two successive passages of the Moon through the same orbital node, which happens once every 27.2122 mean solar days.

MOON. The natural satellite of the Earth. The first celestial body to have been reached by a space vehicle sent from the Earth. The Moon travels round the Earth on an elliptical orbit with a mean velocity of 1.02 km/s. This orbit has a mean eccentricity of 0.0549 and an angle of inclination to the ecliptic of 5° 09′. The period of orbital revolution of the Moon is equal to the period of its rotation about its axis and takes 27 days 7 h 43 min 11.5 s. Only 59% of the Moon's surface can be observed from the Earth and, of this, 18% only under favourable libration. The rest of the Moon's surface (41%) is never seen from the Earth. The mean distance between the Moon and the Earth is 384,400 km. A lunar day (i.e., synodic month) has a duration of 29 days 12 h 44 min 2.7 s. Compared to the Earth, the Moon's diameter equals 0.27 (or 3476 km), mass 0.01 (or $7.35 \cdot 10^{25}$ g), density 0.61 (or 3.34 g/cm^3), volume 0.02 (or $2.2 \cdot 10^{25}$ cm^3), area 0.07 (or $3.8 \cdot 10^7$ km^2), acceleration of gravity at surface 0.16 (or 162 cm/s^2), 1st cosmic velocity 0.21 (or 1.68 km/s), 2nd cosmic velocity 0.21 (or 2.36 km/s). In the centre of the visible lunar disc the maximum daytime temperature is about 130°C, while the minimum night-time temperature is about —150°C. At the boundary of the Earth's atmosphere, the illumination due to moonshine at the full-moon phase amounts to 0.32 lux. The mean reflectivity of the visible lunar surface equals 7%.

On September 14, 1959, the automatic interplanetary station *Luna-2* reached the Moon. The station delivered to the surface of the Moon a pennant carrying the Coat of Arms of the USSR. Automatic interplanetary station *Luna-3* photographed the far side of the Moon on October 7, 1959. The *Ranger-7* spacecraft on July 31, 1964, took close-up photographs of the visible side of the Moon. The automatic interplanetary station *Zond-3* completed the global photographing of the far side of the Moon on July 20, 1965. On February 3, 1966, the automatic interplanetary station *Luna-9* made the first soft landing on the surface of the Moon. On April 3, 1966, *Luna-10* went into orbit round the Moon to become its first satellite. The scientific data obtained by the Soviet artificial interplanetary station *Luna-3* and *Zond-3*, revealed that the Moon surface has a terrestrial structure (which was fully confirmed by the data obtained subsequently from the American Moon satellite *Lunar Orbiter*). The maria regions occupy about $^1/_4$ of the entire

lunar surface and are situated mainly on the visible side. Craters comprise a major portion of the Moon terrain. On the visible side alone they number over 300,000 (dia $>$ 1 km). On the far side, their average concentration is still greater. A large number of crater chains was noted, the longest being discovered on the far side; their maximum length is about 1000 km (from photographs taken by *Zond-3*). The mountain ranges of the Moon (Lunar Alps, Lunar Apennines, etc.) seldom have altitudes higher than 6 km, and only solitary peaks rise to altitudes of 7—8 km. At full moon, i.e., when viewed from the side of the Sun, systems of light-coloured rays emanating from several large craters are clearly visible on the Moon's surface. These ray systems are also seen on the photographs taken by automatic stations *Luna-3* and *Zond-3*. Besides the structural features mentioned above, the lunar terrain includes cracks, valleys, faults, folds, and dome-shaped objects. The maria have a relatively smooth surface, presumably lava flooded fields, and in some places they are covered with craters, ridges, cracks, and folds.

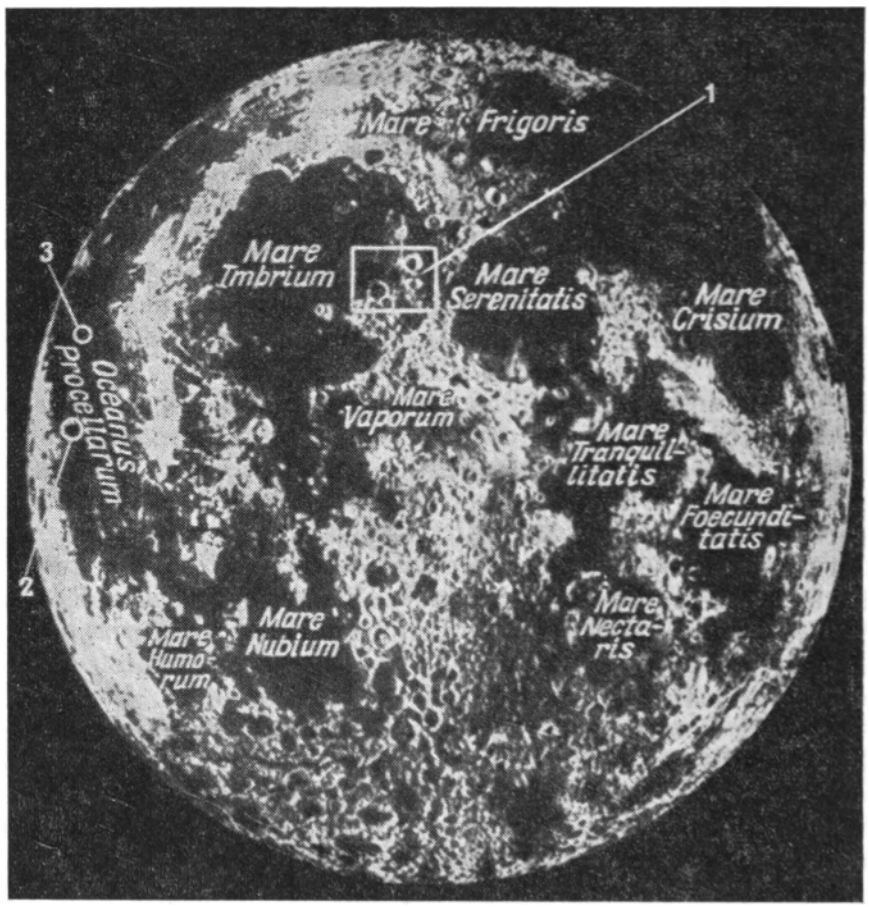
Photometric, polarization, and radar observations have established that the surface of the Moon is markedly rugged and rough. The first panoramic photographs of the micro-relief of the lunar surface were obtained with the aid of *Luna-9*. These photographs showed that the Moon's surface is not covered with a thick layer of dust, but has a large number of small irregularities that partially resemble a porous structure, etc. Unexpectedly, the photographs revealed a large number of rocks. From a study of their bedding in the Moon's soil it was possible to estimate the load-bearing capacity of the ground at a value of no less than several kg/cm^2. This means that spacemen and transport vehicles will be able to move on the surface of the Moon. Data obtained by the *Luna-13* station and the American *Surveyor* station confirmed that there was no dust layer on the Moon and made possible a more accurate determination of the physical properties of the ground.

The automatic lunar stations *Surveyor-5*, *6* and *7* made analyses of the chemical composition of lunar soil. They revealed that in oxygen and silicone contents (about 57—58% and 18—20% of atoms, respectively) the soil approached terrestrial basalts. Some 6.5—8% of aluminium and 3—4% of magnesium were found. Colour photos taken by *Surveyor* and visual observations from *Apollo-8* and *-10* show that dominating on the Moon are gray and brown shades.

Interplanetary station *Luna-2* showed that the Moon had practically no magnetic field. At a height of 55 km from the lunar surface the intensity of the magnetic field is less than $3 \cdot 10^{-4}$ oe. This was confirmed by measurements taken by the *Luna-10* lunar satellite. Presumably, the Moon has no fluid core where eddy currents could appear and give rise to a magnetic field. Lunar satellites have provided much new scientific information regarding gamma radiation intensity, cosmic ray reflectivity, close-up photographs of the lunar surface, etc.

The photos of the far side of the Moon taken by *Luna-3* (1959) and *Zond-3* (1965) automatic interplanetary stations were studied by the P. K. Sternberg State Astronomical Institute and a number of other bodies. This study resulted in the publication of an *Atlas of the Far Side of the Moon* (pt. 1, 1960; pt. 2, 1967). The scientific editor of the *Atlas* was Yu. N. Lipsky, D. Sc.

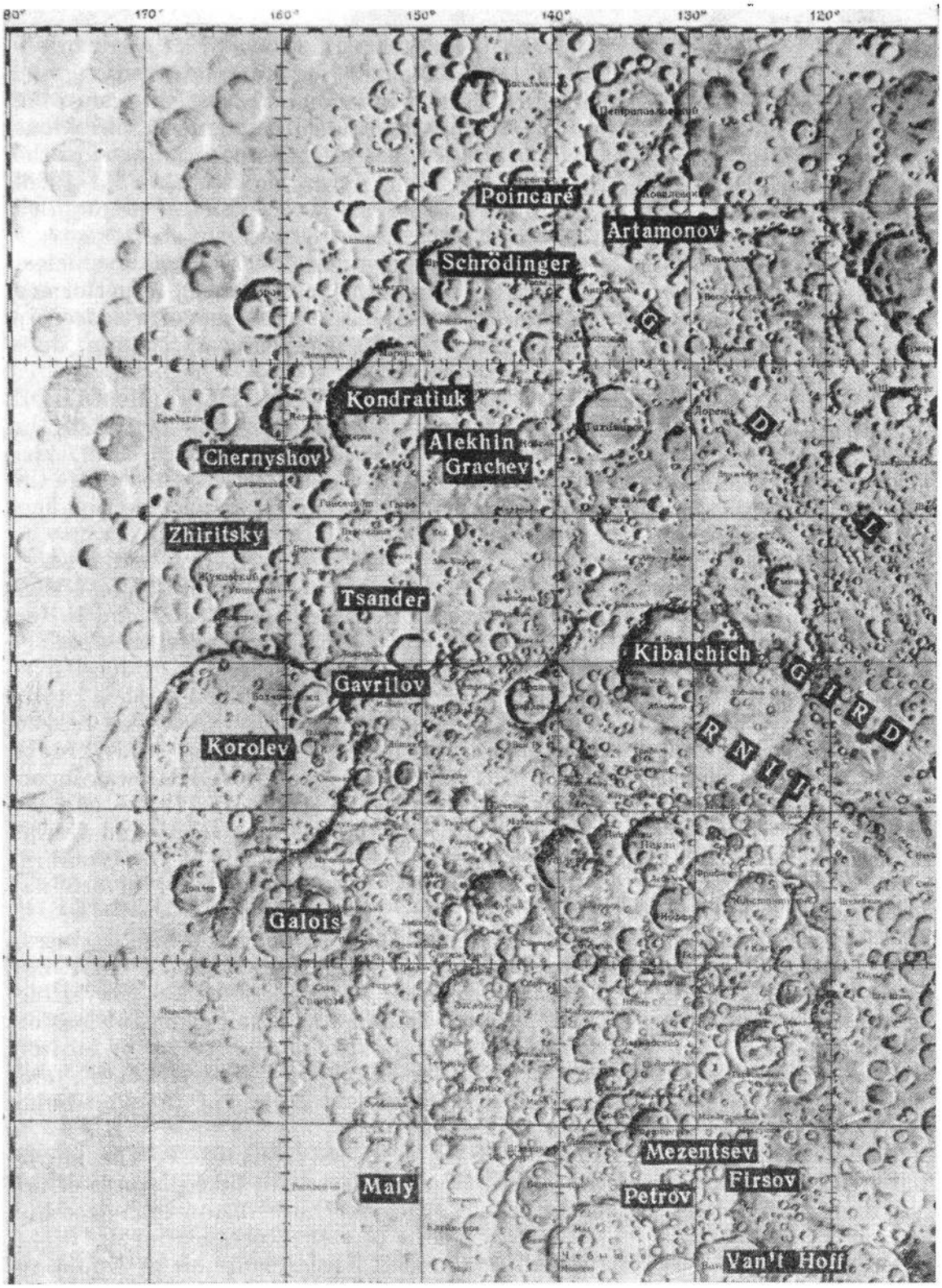
(Phys. & Math.). Appended to the *Atlas* was a catalogue listing about 4000 newly-found formations. The Commission for Naming of Formations on the Far Side of the Moon, established by the Academy of Sciences of the USSR, used the right of the discoverer to name some 250 formations in honour of Soviet and foreign scientists (in 1960, 1966, 1967, and 1968). The



Map of the Moon.
1—site of lunar impact of automatic interplanetary station *Luna-2*; *2*—landing site of *Luna-9* station; *3*—landing site of *Luna-13* station.

names of those who made contributions in cosmonautics and rocket engineering included Kibalchich, Meshchersky, Tsiolkovsky, Kondratiuk, Tsander, Korolev, Rynin, Ganswindt, Tikhomirov, Gagarin and Komarov. Chains of craters were named after GDL, GIRD and RNII, the first Soviet organizations to do research work in rocket engineering and to make fundamental contributions in the development of Soviet rocket-space science and engineering. The region of the first lunar impact (*Luna-2*) was named Sinus Lunnik (Lunnik Bay), the region of first soft landing on the Moon (*Luna-9*) received the name of Sinus Landing (Landing Bay).

The *Atlas of the Far Side of the Moon* and the known photos of the near



First complete map of Moon compiled to photographs taken by *Luna-3* and *Zond-3* and photographic atlases of near side of Moon (fragment).

side of the Moon were used for the preparation in 1966—67 of the world's first *Complete Map of the Moon* (1 : 5,000,000) and complete lunar globe (1 : 10,000,000), published by the State Astronomical Institute and the Topogeodetical Service of the USSR; the scientific editor of the publications was Yu. N. Lipsky. An atlas containing 7 maps of the equatorial zone of the visible hemisphere of the Moon (1 : 1,000,000) was made public in 1968. Later, the USA published a complete map of the Moon which was compiled on the basis of photos taken by *Zond-3* and *Lunar Orbiter*.

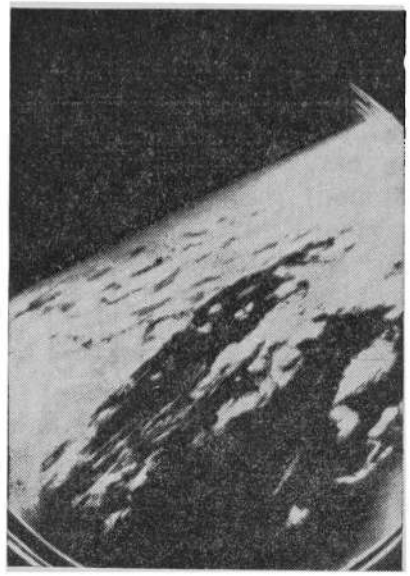
MOORING. A soft approach and temporary coupling of two space vehicles, such as by means of a cable or other suitable means. Mooring is performed for carrying out inspections, rendering assistance to the crew of a spaceship in case of an emergency, relieving the crew of a manned space station, delivery of cargo (propellant, life-support materials), etc.

MOSCOW GROUP FOR STUDY OF REACTIVE MOTION (MosGIRD). A public organization set up in Moscow under the research sector of the Central Council of the Osoaviakhim Society for Assisting Defence and Aviation and Chemical Construction in the USSR on August 18, 1931, to unite the efforts of individual enthusiasts of rocketry. Its organizers and active members included F. A. Tsander (the first head of MosGIRD), S. P. Korolev, who shortly replaced Tsander as the head of the group, B. I. Cheranovsky, V. P. Vetchinkin and Y. A. Pobedonostsev, and public figures. MosGIRD widely popularized the ideas of reactive motion through lectures and in the press, arranged courses in the theory of reactive motion and started designing the aircraft liquid-propellant engine *OP-2* and the rocket glider *РП-1*. The successful work of MosGIRD and LenGIRD attracted broad public attention to problems of rocket technology. MosGIRD, which was ranked as the central group, rendered assistance to reactive movement study groups and circles in other Soviet cities. In 1932, the staff of MosGIRD was incorporated in the Group of Study of Reactive Motion. In 1934, popularization and educational functions were reserved for MosGIRD and it was re-organized into the Reactive Group of the Central Council of Osoaviakhim which continued work till late 1930's and created a number of original small-size experimental rockets.

MOTION SICKNESS. This is manifested by a complex of symptoms (dizziness, pallor, excessive perspiration, tachycardia, salivation, nausea, vomiting) caused by long-time action of vestibular stimulants when travelling by various means of transport. The main role in the development of motion sickness belongs to long-acting linear accelerations. The forms of motion sickness are sea sickness, air sickness, so-called "satellite sickness", etc. The best way of preventing motion sickness is training of the vestibular analyzer (see Vestibular training).

MOVIE AND STILL CAMERA EQUIPMENT OF SPACECRAFT. The movie and still cameras on board a spacecraft, which permit to take pictures of the Earth and other celestial bodies and of spacemen both inside the spaceship and on a "space walk", as well as to record certain processes during flight (approach and docking of spacecraft in orbit, behaviour of a liquid in weightlessness, etc.). Such shots, taken on black-and-white or colour film, permit much valuable data to be obtained for many branches of science

(astronomy, geophysics, meteorology, space biology, space medicine, etc.). They also serve the purpose of solving a number of engineering problems. Of particular importance are the moving pictures and still shots taken of the surfaces of other celestial bodies (the Moon, Mars), as well as of the movements of spacemen in free space. Motion pictures of the Earth were first taken from the *Vostok-2* spaceship. A record of the first exit of a spaceman from his ship into free space was obtained with the aid of a movie camera arranged within a sealed observation



An early photo of the Earth as seen from the outer space. This photo was taken by Pilot-Cosmonaut G. Titov during orbital flight at an altitude of 250 km.

compartment on the Soviet spaceship *Voskhod-2*. Moving picture and still camera shots were also taken on the American spaceship *Gemini*. Photographic equipment of a specialized nature must go into the TV systems installed on automatic spacecraft launched to photograph other celestial bodies.

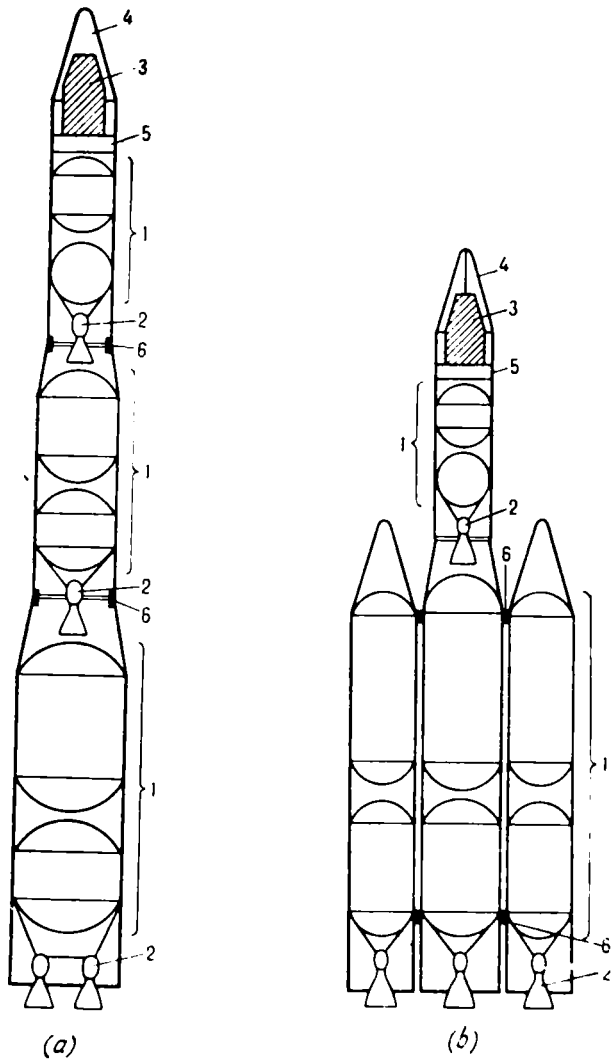
MULTI-CHAMBER ROCKET ENGINE. A liquid-propellant engine with several thrust chambers and a common system of propellant feeding, control, automation, and framing (e.g., the Soviet liquid-propellant engines *РД-3*, *РД-107*, *РД-108*, *РД-214*, etc.). At the same thrust multi-chamber rocket engines are shorter than single-chambered ones, this making it possible to reduce the rocket's overall weight. It has some advantages in finishing the thrust chamber, but is more sophisticated. Solid-propellant engines are sometimes made with several chambers for a step-by-step changing of thrust.

MULTI-PHASE FLOW. The motion of a medium consisting of several phases (e.g., the gaseous, solid and liquid). This can be the flow of combustion products in a rocket engine when the propellant contains metals and metalloids that recondense into the solid phase. In multi-phase flow the velocities and temperatures of the condensed particles are lower than those of the gas, leading to a loss of the specific impulse. These losses are the bigger, the greater the size of the condensed particles. Therefore agglomeration in the nozzle lessens specific impulse.

MULTI-PROPELLANT. A rocket propellant consisting of several separately stored components (oxidizers and fuels), e.g., a TRIPROPELLANT. In addition, it can contain an inert component (that does not participate in burning) with a low molecular weight to increase the specific impulse, or with a high density to increase the EFFECTIVENESS OF ROCKET PROPELLANT.

MULTI-STAGE ROCKET. A rocket consisting of several separate stages used in succession, one after another. When one stage operates, the successive stages are the PAYLOAD for it. After the propellant of the operating stage

Multi-stage rocket



Schematic diagram of a multi-stage (3-stage) rocket: (*a*) successive arrangement; (*b*) cluster arrangement.

1—propellant bays; *2*—rocket engines; *3*—payload; *4*—nose cone; *5*—control instrumentation compartment; *6*—stress-bearing interstage joints.

is expended and its rocket engine is cut-off, the stage (or a part of it, e.g., propellant tanks or the engine) is jettisoned, the weight of the remaining part of the rocket decreases and it can be imparted a velocity higher than that of a single-stage rocket of the same initial weight with the same propellant capacity and payload weight.

A multi-stage rocket can have a successive arrangement of stages (with transverse division) or the so-called "cluster" design (with longitudinal division); the former-type rockets have their engines of separate stages operating in succession, one after another, while the engines of the latter-type rockets can operate simultaneously with the engine of the previous stage.

Multi-stage rockets operating on chemical propellant are capable of developing the 1st and 2nd cosmic velocities and employed for launching space bodies.

Mutual visibility zone

Description of a multi-stage rocket of cluster design with longitudinal division of stages dates back to Kazimierz Siemienowicz (*Artis magnae artilleriae*, Amsterdam, 1650). Cluster rockets were described and theoretically discussed by R. Goddard (1919) and H. Oberth (1923). The theory of multi-stage rockets was further developed by K. Tsiolkovsky in his article *Raketnye poyezda* (*Rocket trains*, 1929) introducing new ideas (transfusion of propellant components from one stage to another while the clustered stages work simultaneously, and others).

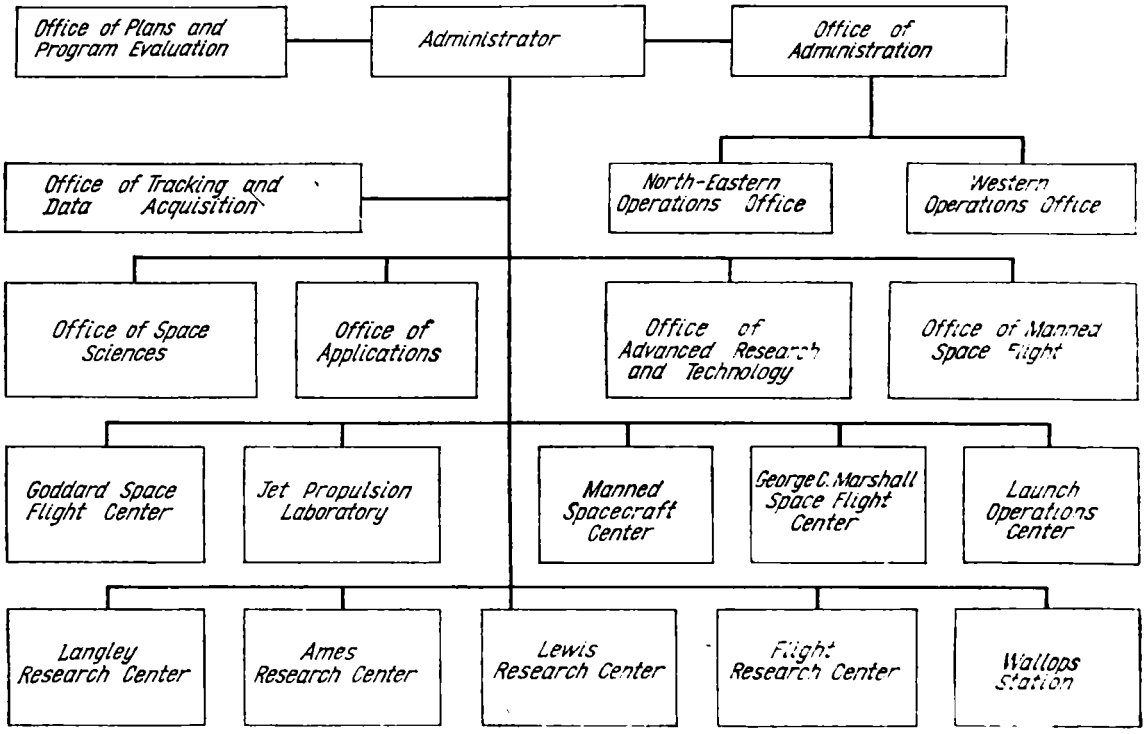
MULTI-UNION CONNECTOR. A quick-release connector for coupling the pneumatic pipelines of the launcher and the launch vehicle. It is used when the launch vehicle is on the launch pad or under test. The number of connections may range from 5 to 65 for a single launch vehicle. The multi-union connector is made up of two parts; the upper part relates to the launch vehicle, while its lower reciprocal, incorporating the mechanism for mating the connector and holding it in the operational attitude, is an element of the launcher. The lower part incorporates several pipe unions, that fit into the corresponding sockets of the upper part and are sealed with renewable rubber V-rings. The multi-union connectors are disengaged by the launch vehicle itself during the take-off.

MUTUAL VISIBILITY ZONE. For communication between a satellite and an Earth station, the zone of a definite radius around the given Earth station within which the satellite should be so as to ensure line-of-sight communication between them. The radius of this zone depends upon the altitude of the satellite orbit. For communication via an Earth satellite, the zone of mutual visibility is to provide simultaneous visibility of the satellite from all Earth stations maintaining communication, i.e., the satellite is to be within the limits of mutually overlapping sections of the zones of all the stations.

N

NADIR. The point of the CELESTIAL SPHERE that is directly opposite the ZENITH and vertically downward from the observer.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA). A US government body set up on October 1, 1958. The structural nucleus of the NASA was formed by its predecessor, the National Advisory Committee for Aeronautics (NACA). The activities of the NASA are aimed at: explorations of the Earth atmosphere, outer space and cosmos; research and development in the field of aircraft and spacecraft design; providing a leadership



Structure of National Aeronautics and Space Administration (USA).

for the USA in aeronautics, space science and technology; studies in the potential benefits to be derived from the advance of aeronautics and astronautics and their peaceful utilization; coordination of the efforts of governmental, industrial, and scientific bodies in aeronautics and astronautics in order to employ effectively the US resources and to avoid parallelism of effort; and the US cooperation with other countries in the field of astronautics and space exploration.

NAVIGATIONAL SYSTEM. A system comprising a group of ground navigational stations and navigation satellites. The ground stations pre-determine, with high accuracy, the parameters of the satellite's motion for a certain period of time, e.g. for a day, ahead. This information is attached to a common time, transmitted to the satellite, and recorded in space-borne memory units. During the flight, the satellite regularly transmits its coordinates.

Receiving them and determining the position with respect to the satellite, any object on the Earth can find its own coordinates.

NAVIGATION SATELLITE. An Earth satellite which serves for ship and aircraft navigation. Systems of radio navigation provide for determination of the position of the ship (aircraft) relative to the satellite at several points along its orbit. Knowing the orbit of the satellite and the moment of measurement, the coordinates of the satellite at these points may be determined relative to the Earth system of coordinates. Usually, the current parameters of the orbit are stored in the memory unit of the satellite and relayed to the ship or aircraft by radio during a session of navigation. The navigation satellites already in orbit have operated at heights ranging from 800 to 3000 km. The American *Transit* satellites are an example of navigational satellites.

NEPHELOMETRIC ANALYSIS. The analysis of schematic cloud maps, plotted on the basis of TV or IR pictures of the Earth obtained by means of meteorological satellites.

In short-term weather forecasting, nephelometric analysis is the principal source of information on cloudiness. Daily nephelometric analysis maps are transmitted from world regional and national METEOROLOGICAL CENTRES to weather bureaus for use in weather forecasting.

NEPTUNE. The 8th planet in the order of distances to the Sun. The mean distance to the Sun is 30.057 AU (4496 million km), the orbital eccentricity 0.0086, the inclination of orbital plane to ecliptic 1° 46.4′. The mean orbital velocity is 5.4 km/s, the sideral revolution period 164.788 years. The equatorial dia of Neptune is 44,600 km, or 3.5 (Earth = 1), the compression 1 : 58, the mass 17.22 (Earth = 1) or 1.03×10^{29} g, the mean density is 2.22 g/cm^3, the gravitational acceleration is 1.38 (Earth = 1) which is equal to 13.47 m/s^2. The 2nd cosmic (parabolic) velocity on the planet is 24.6 km/s. The period of rotation about the axis is 15.8, the inclination of the equator to the orbital plane is 29°. The main atmospheric constituents are methane and hydrogen; the amount of methane is estimated at 2500 m thickness at standard temperature and pressure, the amount of hydrogen has not been established. Neptune has two satellites, approx. 4000 and 300 km in dia.

NETWORK OF RADIO RELAY LINES. A combination of several radio relay communication lines having a common intermediate relay point. Frequency, time, or code separation of radio signals may be provided for this system of communication. In the 1st case the signals are transmitted along the lines at different frequencies, in the 2nd case, in succession, and in the 3rd, by encoding. For space radio communication, it is advantageous to use a common satellite as the common intermediate point.

NEUTRALIZATION OF PROPELLANT. Decontamination of vapours and liquid phase of toxic and aggressive propellants with chemical neutralizers. When fuelling the launch vehicle, ventilating the ullages in the propellant tanks, filling and depressurizing the propellant tanks, it is necessary to neutralize the mixture of air or gaseous nitrogen with vapours of the propellant. While the launch vehicle tanks are being filled or drained, propellants may get spilled because of leaky pipe joints and loose fuelling connectors. In such a case, the liquid propellants have to be neutralized. Fuel vapours can be

Neutralization of rocket

neutralized by burning or by the use of chlorine-containing agents for which purpose the fuel vapours should first be dissolved in hot water by means of atomizers. The oxidizer vapours are neutralized by burning or by absorption of vapours by an alkaline solution. Liquid fuel is neutralized in tanks by chlorine agents followed by evaporation in evaporating basins. The fuel vapours and active chlorine liberated during the reaction of propellant neutralization are vented into the atmosphere at least 8 m above the ground or, in case of particularly large installations, are directed into absorbers where they are fixed by chemical reagents. Liquid oxidizers are neutralized by alkaline solutions.

NEUTRALIZATION OF ROCKET. Chemical neutralization of the launch vehicle and removal of the non-drainable aggressive and toxic propellant residue from the propellant tanks and hydraulic lines of the powerplant after the propellants have been drained following an abortive launch. Neutralization is performed by means of gases or liquids selected according to the chemical properties of propellant constituents. After neutralization the tanks and hydraulic lines are dried with hot air or nitrogen. If neutralization is incomplete, being carried out only to gain concentrations harmless to man, the process is referred to as decontamination. Neutralization and decontamination are applied also to structures, hoses, pipelines and pipe fittings of fuelling systems.

NEUTRALIZATION STATION. A complex of structures and devices designed for neutralizing the oxidizer and fuel in vapours and in the launching-site drains and for feeding the products of neutralization to the evaporation area where precipitation and water evaporation occurs. The neutralization station includes tanks for neutralizing the drains, adsorbers for entrapping the oxidizer and fuel vapours, a pump plant, and units for the preparation of neutralizing solutions.

NEUTRON ALBEDO. The effect of the formation, in the Earth's outer atmosphere, of neutrons of various energies, disintegrating into charged particles and neutrinos, as a result of the atmosphere's interaction with primary cosmic radiation. That the neutron albedo is the source of high-energy radiation in the GEOMAGNETIC TRAP is one of the earliest hypotheses concerning the origin of the RADIATION BELT OF EARTH. The products of neutron decay, protons and electrons, are charged particles, and if the decay takes place within the field's capturing region they are trapped by the Earth's magnetic field. Detailed investigations revealed that the neutron albedo as a source of trapped particles is relatively effective only in the inner (nearest to the Earth) regions of the geomagnetic trap, i.e., the so-called inner radiation belt; however, even in this region it only partly explains the origin of the trapped radiation.

NIKOLAYEV, Andriyan Grigoryevich (born 1929, Shorshely village, Marinsky-Posad District, Chuvash ASSR). Pilot-cosmonaut of the USSR, colonel. Member of the CPSU since 1957. Hero of the Soviet Union. Finished a school of forestry in 1947; was a forest range foreman in Karelia until 1950. Graduated from an Air Force school for pilots in 1954 and served as an Air Force pilot. Graduated from the Air Force Engineering Academy in Moscow in 1968. Between August 11 and 15, 1962, on board the *Vostok-3*

he orbited the Earth more than 64 times in 94 h 22 min, covering over 2.6 million km. On August 12, the *Vostok-4* piloted by P. R. POPOVICH was put into orbit. The group flight made in space by Nikolayev and Popovich lasted approximately 3 days. Two-way communication was maintained between the ships; the closest distance between them was about 5 km. Live telecasts were conducted from the spaceships.

NIMBUS. The name of a series of American experimental meteorological satellites; 4 satellites of this series were orbited in 1964—69. The instrumentation of *Nimbus* includes TV, IR and actinometric equipment.

NITRIC ACID, HNO_3. A high-boiling oxidizer for liquid-propellant rocket engines. A colourless, hygroscopic, fuming pungent liquid; density 1.52 g/cm^3 at 20°C; m.p.—41.6°C; b.p. 86°C. From yellow to brown in colour if dissolved nitrogen peroxide is present. Poisonous. Explosion-proof, thermally unstable. Additions of nitrogen tetroxide and water are used as stabilizers against thermal decomposition. Inhibitors are introduced to lessen corrosiveness. When mixed with a number of fuels (AMINES, HYDRAZINE and its derivatives, etc.) forms SELF-IGNITING PROPELLANTS. Does not attack stainless steels, most of the aluminium alloys, and some other structural materials. Is usually employed in the form of nitric acid oxidizers that display high effectiveness. The nearly pure acid is sometimes called white fuming nitric acid (because of the colour of the vapours); that containing nitrogen peroxide is referred to as red fuming nitric acid. It is cheap and widely available, being one of the principal products of the chemical industry, obtained, mainly, by oxidation of ammonia. Extensively used in rocket engineering in combination with various fuels, e.g. KEROSENE, TURPENTINE, ANILINE, and unsymmetrical DIMETHYL HYDRAZINE. Nitric acid as oxidizer was proposed by the GDL in 1930.

NITRIC ACID OXIDIZERS. Oxidizers for liquid-propellant engines prepared on the basis of NITRIC ACID; these are solutions of nitrogen oxides in nitric acid that are more effective than nitric acid alone: they provide a larger specific impulse and have a higher density and a lower freezing point. Extensively used together with unsymmetrical DIMETHYL HYDRAZINE, as well as with KEROSENE, AMINES and TURPENTINE. Nitric acid oxidizers were first developed in 1930 in the GDL.

NITROGEN BINDING. Conversion of molecular nitrogen into ammonium salts and nitric acid. When certain physicochemical methods are applied for MINERALIZATION of human metabolic by-products and other wastes of the BIOCOMPLEX, considerable amounts of molecular nitrogen are produced. This causes nitrogen disbalance in LSS based on RECYCLING OF SUBSTANCES. Hence, such systems require rebinding of nitrogen. Ammonium salts may be used directly in preparing nutrient solutions for higher and lower plants, while nitric acid is used to dissolve the solid phase of mineralization in preparation of nutrient solutions.

NITROGEN-CONTAINING FUELS. Liquid fuels for rocket engines, whose molecules contain nitrogen atoms. Often form self-igniting propellants (see AMINES, HYDRAZINE).

NITROGEN TETROXIDE, N_2O_4. A high-boiling oxidizer for liquid propellant engines. A highly volatile liquid changing in colour from light yellow

(at —10°C) to reddish brown (at 21°C). The change in colour is caused by the formation of nitrogen peroxide as a result of dissociation (a reversible reaction); density 1.45 g/cm³ at 20°C; m.p. —11.2°C; b.p. 21.2°C; Poisonous. Forms self-igniting propellants with some fuels (e.g., HYDRAZINE and its derivatives). Explosion-proof and stable. Attacks structural metals to a lesser degree than nitric acid does. Traces of water, however, substantially increase its corrosive action. Nitrogen tetroxide is an intermediate product of nitric acid production. It is cheap and widely available. It produces a greater specific impulse than nitric acid, but it is inferior to the latter in handleability because it remains in the liquid state within a narrower temperature range. Nitrogen tetroxide is extensively used in rocket and space technology in combination with MONOMETHYL HYDRAZINE, unsymmetrical DIMETHYL HYDRAZINE, and AEROSENE-50. Liquid-propellant engines with nitrogen tetroxide as oxidizer were developed and tested at the GDL in 1930—31, and introduction of nitric oxide into the nitrogen tetroxide oxidizer was proposed in order to lower its freezing point to —40°C.

NITROMETHANE, CH_3NO_2. A monopropellant for liquid-propellant engines; an oily colourless liquid, density 1.13 g/cm³; m.p. —28°C; b.p. 101°C.

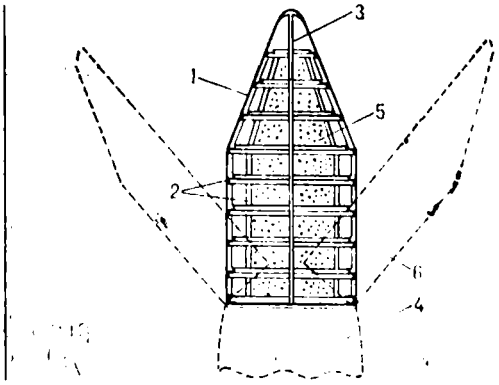
NOISE TEMPERATURE. The temperature, expressed in degrees of absolute temperature, of an equivalent resistance producing a noise of an intensity equal to that generated by the given device or object (antenna, radio receiver, medium, atmosphere, or any other source of noise). The noise temperature is a most convenient index for evaluating and calculating the performance of highly sensitive systems of communication.

NON-CORRECTED GYROSCOPE. See FREE GYROSCOPE.

NON-STATIONARY SATELLITE. An Earth satellite travelling in respect to the Earth's surface. The majority of satellites have been launched into non-stationary orbits.

NORMAL SPEED INDICATOR. An instrument installed on the launch vehicle so as to measure its speed component lying in the vertical plane normally to the preselected flight path (normal speed of the launch vehicle). In the simplest case, the system of control employing a normal speed indicator maintains the normal speed of the launch vehicle at zero value and thus keeps its motion strictly on the preset trajectory.

NOSE CONE. A structural element of a launch vehicle forming the streamlined surface of its nose in flight through the atmosphere. Usually is shaped



Nose cone diagram.

1—shell; *2*—stress-bearing elements (frames and stringers); *3*—joint between nose cone sections; *4*—last stage of the launch vehicle; *5*—payload spacecraft (shown schematically); *6*—position of nose-cone sections during disengagement.

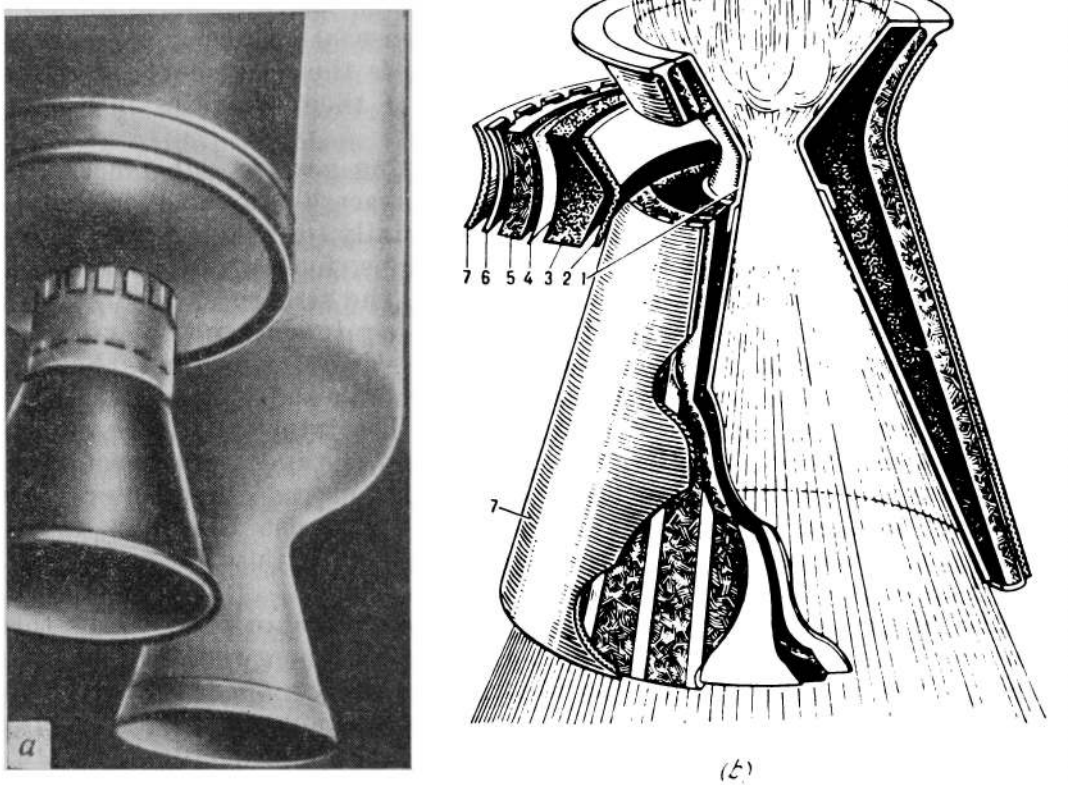
as a cone transient into a cylinder; it consists of a thin-walled shell reinforced from within by longitudinal and transverse STRESS-BEARING ELEMENTS. The nose cone encloses the spacecraft (and sometimes the upper stage of the rocket), shielding it from aerodynamic and heating effects during the rocket's flight at great speed through the dense atmospheric layers. After emergence beyond the limits of the atmosphere the nose cone is jettisoned by a disengagement mechanism (sometimes it then separates into several parts).

NOXIOUS CONTAMINANTS. Toxic or irritating gaseous substances which may contaminate the cabin atmosphere of a spaceship and adversely affect the human organism and equipment (especially during sustained space flights). Examples of these are human excretions, food waste, contaminants emitted by sanitary and hygienic equipment, the structure, decorative and protective materials of the spaceship and its equipment, heat carriers, etc. The human organism can excrete over 400 various substances belonging to 22 chemical groups: carbon monoxide, ammonia and its methylated derivatives, ketones, aldehydes, fatty acids, etc. The intensity of the excretion varies within considerable limits, depending on the individual peculiarities of the organism, the nature of the work done, food and other factors. When estimating noxious contaminants, consideration must be given to their reactions with one another, and to their interaction with water and the principal gases of the cabin atmosphere.

NOZZLE of a rocket engine (jet nozzle). One of the main parts of the thrust chamber of a rocket engine, in which the thermal energy of the compressed working fluid is transformed into kinetic energy, i.e. the gas flow is accelerated to the velocity of exhaust. The nozzle entrance is its subsonic converting part which in the nozzle's narrowest part (throat) is linked with its supersonic diverging part. The OPTIMUM CONTOUR NOZZLE should be used to ensure the best performance of the nozzle (the highest specific impulse, a smaller cooled area, lower weight, smaller size, etc.). The cooling of the nozzle is a complicated problem because of high temperatures and pressure of the working fluid, formation (sometimes) of the condensed phase and aggressive components, and high expansion of the gases in the nozzle. The nozzle is usually made integral with the combustion chamber.

NOZZLE ALTITUDE. The flight altitude at which the rocket engine's nozzle functions as estimated, i.e. with the expansion of gases to ambient atmospheric pressure. At a lower altitude a non-adjustable nozzle will produce a lower thrust because of an over-expansion of the gases. At a higher altitude the thrust will increase due to the pressure difference at the nozzle exit, but this increase will be smaller than for a nozzle with a correspondingly increased altitude rating (see NOZZLE EXPANSION RATIO).

NOZZLE EFFICIENCY. The ratio of the actual thrust coefficient of a rocket engine (thrust complex) to the theoretical one (see THERMODYNAMIC ANALYSIS OF ROCKET ENGINE) as computed for the same values of the EXCESS-OF-OXIDIZING ELEMENTS COEFFICIENT, the geometrical NOZZLE EXPANSION RATIO, and chamber pressure (STAGNATION PRESSURE in the nozzle throat). Nozzle efficiency is also equal to the ratio SPECIFIC IMPULSE EFFICIENCY to COMPLETENESS-OF-PRESSURE. Nozzle efficiency characterises friction losses in the subsonic and



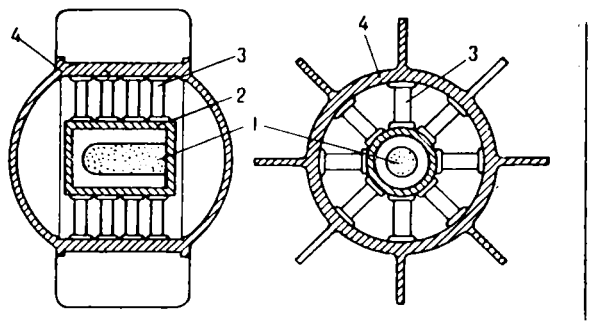
Jet nozzle of a solid-propellant engine: (*a*) outside view; (*b*) section.
1—tungsten interior lining; *2*—intermediate layer of refractory material; *3*—carbon heat absorber; *4*—ceramic insulation; *5*—plastic insulation; *6*—stress-bearing structure; *7*—glassfiber external shell.

supersonic parts of the nozzle, losses in nozzle due to irregular flow, nature of the multi-phase flow, etc. Nozzle efficiency is usually equal to 0.94—0.98.

NOZZLE EXPANSION RATIO. An important parameter of a rocket engine, determining quantitatively the expansion of the working fluid in the nozzle. The nozzle expansion pressure ratio is equal to the ratio of chamber pressure (to be more exact, the stagnation pressure of the working fluid in the nozzle throat) to the mean pressure in the nozzle exit. The nozzle expansion area ratio is equal to the ratio of the areas of the nozzle exit and the throat. When the mean pressure in the exit area is equal to the ambient atmospheric pressure, such a nozzle expansion ratio is called rated, and the nozzle with such an expansion ratio is called a rated nozzle. Other conditions being equal, any deviation from the rated ratio leads to a lower thrust. The choice of the nozzle expansion ratio for a rocket engine depends on the powered flight path of the rocket and the nozzle weight characteristics. Thus, the nozzle of the *РД-107* engine of the 1st stage of the *Vostok* rocket has a pressure ratio of 150 and an area ratio of 19; for the *РД-119* engine of the 2nd stage of

the *Cosmos* rocket the pressure ratio is 1350 and the area ratio is 100. A nozzle with an expansion ratio lower than rated is termed underexpanded, that with a ratio greater than rated, overexpanded. When overexpansion is big, a system of shock waves enters the nozzle, thus reducing overexpansion losses. In ground-level conditions, the rocket nozzle is usually overexpanded at launching. As the rocket ascends, this overexpansion lessens, and at a certain altitude the nozzle functions as rated. Further up, however, it begins to operate as underexpanded, the degree of underexpansion increasing with altitude.

NUCLEAR-ISOTOPE BATTERY. A source of electric energy in a spacecraft power supply system. It contains isotopes whose radioactive decay produces heat which is converted to electric power by a suitable device, e.g., a semiconductor thermoelectric generator. The heat is applied to the hot-junction surface while the cold-junction surface is cooled by transferring the heat from it into free space by radiation-cooled panels. Due to the Seebeck-Peltier-Thomson effect, the difference in temperature set up between the hot and cold junction produces electric current. A nuclear isotope battery can develop an output of several kW. Its useful life depends on the half-life period of the isotope employed and the parameters of the thermoelectric converter. Batteries of this class have been tested in space on several satellites, e.g., *Cosmos* and *Transit-4A*.

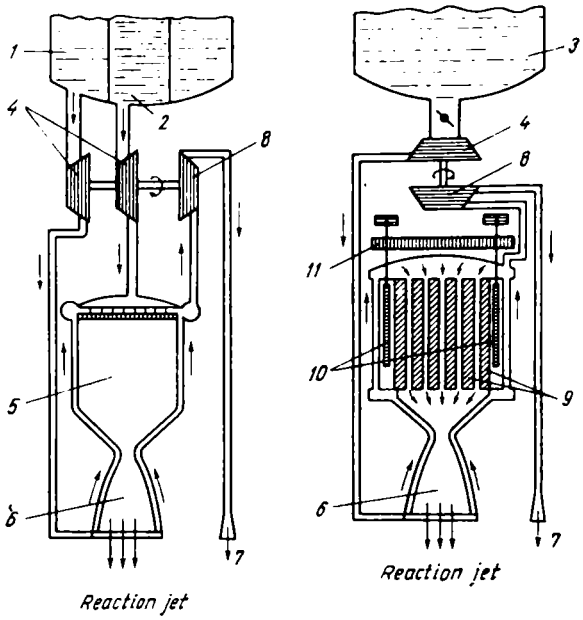


Schematic diagram of elementary nuclear-isotope generator:
1—isotope can; *2*—internal container heated by isotope; *3*—junctions of semiconductor thermoelectric generator; *4*—enclosure fitted with cooling fins.

NUCLEAR PROPELLANT. A substance or combination of substances releasing energy as a result of the nuclear reactions of radioactive decay, division, or synthesis. The energy is carried by the reaction products used in nuclear rocket engines as the working substance or transferred to an extraneous working substance.

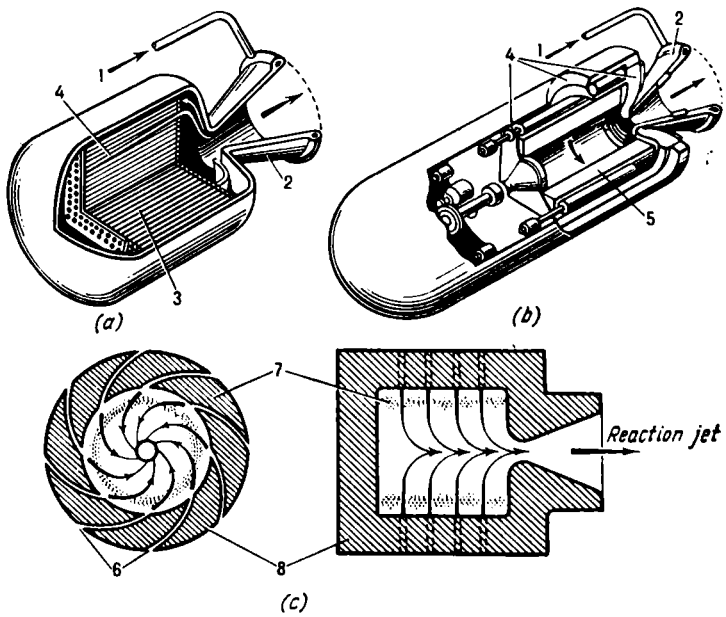
NUCLEAR REACTOR CORE. The part of the reactor where nuclear fuel is contained, nuclear energy is produced due to the reaction of fission of nuclei, and the neutrons for sustaining this reaction are generated. The core contains a moderator and is surrounded by a reflector. The existing nuclear reactors usually have a solid-phase core; reactors with a high-temperature liquid- or gas-phase core are also feasible.

NUCLEAR ROCKET. A rocket with a nuclear engine capable of producing a higher exhaust velocity (specific impulse) and a considerable thrust as compared with chemical rocket engines. Nuclear rockets must be provided with RADIATION PROTECTION against the emissions of the nuclear reactor (especially reliable protection of the crew is required). Nuclear rockets are still in the stage of development.



Schematic diagrams of chemical rocket engine (left) and nuclear rocket engine (right).

1—liquid oxydizer tank; *2*—liquid fuel tank; *3*—liquid hydrogen tank; *4*—pump; *5*—combustion chamber; *6*—nozzle; *7*—turbine gas exhaust; *8*—turbine; *9*—heat releasing elements; *10*—control rods; *11*—protective shield.



Nuclear rocket engines: (*a*) solid-phase core; (*b*) liquid-phase core (melted uranium being held on reactor walls by centrifugal force caused by rotation of the reactor); (*c*) vortex gas reactor (gas vortex composed of uranium and hydrogen).

1—working fluid supply; *2*—nozzle; *3*—reactor core; *4*—circulating working fluid; *5*—reactor; *6*—hydrogen supply; *7*—gasified nuclear fuel; *8*—engine body.

NUCLEAR ROCKET ENGINE. A rocket engine in which NUCLEAR PROPELLANT is the source of energy. In an engine with a nuclear reactor the heat produced by the fission chain reaction is imparted to the working fluid (e.g., hydrogen). The active core of the nuclear reactor may be solid-phase (such a nuclear rocket engine is near completion), liquid- or gas-phase. The energy of radiactive decay is used to propell a radioisotope nuclear rocket engine.

NUTRIENT SOLUTION. Solution containing elements of mineral nutrition (in the form of inorganic salts) necessary for plant growth; in some cases it may also contain urea as the source of nitrogen. The composition and concentration of nutrient solutions for the biocomplex of a LSS of a spaceship may vary depending on the species of plants or strains of algae cultivated, the method of cultivation, and the required quality and biochemical composition of the biomass. The most common medium for algae cultivation contains (per litre): 5 g potassium nitrate, 2.5 g magnesium sulphate, 1.25 g potassium dihydrogen phosphate and 3 mg ferric sulphate. Added to the solution are such microelements as copper, zinc, boron, molybdenum, vanadium, etc.

NUTRIENT SOLUTION REGENERATION. Restoration of nutritive value of the medium used for cultivating the AUTOTROPHS in a spaceship's LSS. It is effected by physico-chemical methods, such as distillation, sorption, extraction, and oxidation, in order to remove or neutralize the accumulated metabolites and excess quantity of some compounds (e.g., sodium chloride). Regeneration permits sustained cultivation of plants with a constant volume of the nutrient medium.

O

OBERTH, Hermann Julius (born 1894). German scientist, one of the founders of rocket and space engineering. Attended the Munich, Göttingen, Heidelberg, and Klausenburg universities. Professor of the College in Mediasch in 1924—38. Experimented with liquid-propellant engines and rockets in 1929. Was invited to the Vienna Institute of Technology in 1938 for development of military rockets (beginning of work on the *V-2* project). Professor of the Dresden Institute of Technology since 1940. Beginning with 1941 worked as consulting engineer at the German Rocket Research Centre in Peenemünde. In 1943 began developing powder-propelled military rockets (at the ordnance factories of the Westfälish-Anhaltinische Sprengstoff AG). In 1945—48 carried out private studies (in Bavaria). Lived in Italy from 1950 to 1953 where he developed rockets for the Italian Navy. In 1955, he moved to Huntsville USA, where he became engaged in the development and modification of rockets. Later returned to Feucht, GFR. Oberth studied several problems relating to the theory of rocket flight and rocket applications for atmospheric studies and space flight. He is the author of the books *Die Rackete zu den Planetenräumen* (*The Rocket to the Planetary Spaces*, München, 1923); *Die Raumschiffahrt* (*Spaceship Travel*, München, 1929); *Menschen im Kosmos* (*Man in Cosmos*, 1954).

OBERTH MEDAL. An award instituted by the Deutsche Gesellschaft für Raketentechnik und Raumfahrt (DGRR) in 1951 which is presented in recog-

Oberth medal.

nition of fundamental research and outstanding achievements in rocket engineering and space flight.

ONE-DIMENSIONAL FLOW. A flow in which all the parameters of the stream depend on one independent variable only. For an approximate estimate, the flow in a rocket nozzle can be regarded as one-dimensional, assuming that the flow parameters across the nozzle are constant.

OPERATION MODE OF ROCKET ENGINE. A characteristic of the operation of a rocket engine determined by the multitude and rate of changes of the thrust, propellant consumption and other parameters. There are transient modes (those at starting, cut-off, change of thrust and mixture ratio during the engine control) and stable-state operation modes of a rocket engine.

OPERATIONAL TESTS. A combination of operations performed for checking the correctness of ground system connections to the space vehicle and the return to initial position of all the systems, parts and components of the space vehicle, as well as that of ground equipment involved in system integration tests.

OPTICAL CHARACTERISTICS OF SURFACE. Relative values describing the capacity of a body to absorb outer thermal fluxes and to radiate heat. The values of optical characteristics of a spacecraft's outer surface must be selected so as to maintain its temperature within the predetermined range. The required optical characteristics of surface are usually obtained by an appropriate finishing or by applying special coatings.

OPTICAL COMMUNICATION. Communication maintained between two or more points by utilizing the optical range of electromagnetic wavelengths (from 1 mm to $2 \cdot 10^{-3}$ μ). This is a very promising means of establishing reliable communication over great distances beyond the terrestrial atmosphere owing to the invention of sources of radiant energy of enormous density (lasers), a high directivity of the radiation, and weak attenuation of optical waves in outer space.

OPTIMUM-CONTOUR NOZZLE. A contour of a jet nozzle derived by variational methods and, on observance of a number of initial conditions, ensuring maximum SPECIFIC IMPULSE.

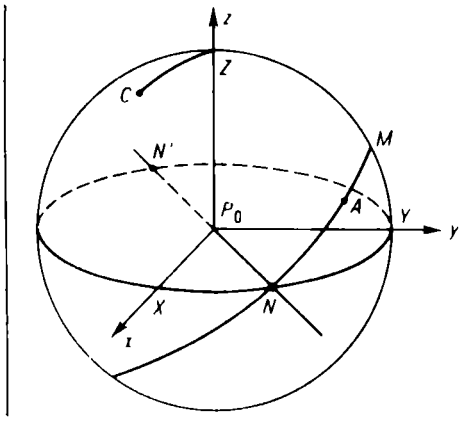
Equations for the calculation of such nozzle were published in the USSR in 1957 by Yu. D. Shmyglevski and L. E. Sternin, and a year later, in the USA by G. V. R. Rao.

OP (OR). Abbreviation of the Russian words for "experimental rocket". *OP-1* was the first jet engine created by F. A. TSANDER in 1930—31. It fired gasoline and gaseous air and developed a thrust of 145 g consuming 1.69 g/s of gasoline mixture with air. *OP-2* was the first liquid-propellant rocket engine designed by F. A. Tsander and intended for the *РП-1* rocket glider of B. I. Cheranovsky design. Its propellant was LOX and gasoline, its rated thrust, 50 kg, the nozzle was cooled by water and the combustion chamber by gaseous oxygen. It was built by GIRD in December, 1932, and disintegrated during preliminary tests (March—April, 1933). Tsander's followers re-designed the *OP-2*; gasoline was replaced by ethyl alcohol to lower the temperature of the gases and make cooling easier, the thrust chamber was lined with ceramics, and the engine's designation was changed to *02*.

ORBIT (trajectory). The path in which a planet, a satellite, a spacecraft, etc., moves. This term is sometimes applied in a broader sense to include the law of motion of a body.

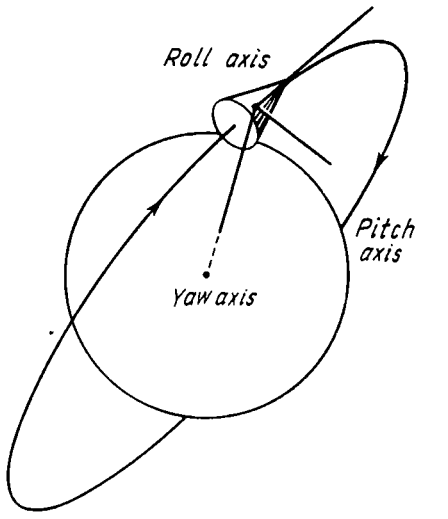
ORBITA. The name of the first space system for long-range radio communication created in the USSR on the basis of the *Molniya-1* satellites. The system comprises a number of transmitting stations and a great many receiving stations located in various regions throughout the USSR. Operational by January 1969 were stations located near Moscow and Vladivostok, Murmansk, Archangel, Syktyvkar, Vorkuta, Norilsk, Surgut, Ashkhabad, Frunze, Alma-Ata, Novosibirsk, Kemerovo, Krasnoyarsk, Bratsk, Irkutsk, Ulan-Ude, Chita, Yakutsk, Magadan, Petropavlovsk-on-Kamchatka, Komsomolsk-on-Amur, Blagoveshchensk, Khabarovsk, and Yuzhno-Sakhalinsk. The *Orbita* system ensures TV relaying and two-way telephone, telegraph and phototelegraph communication between a number of stations. Orbits of the *Molniya-1* satellites are chosen so that the duration of a communication cycle via each satellite is no less than 8—10 h daily (3 or more satellites, simultaneously in orbit and synchronized in motion, can ensure round-the-clock radio communication). The system's frequency range is 800—1000 Mc/s. Ground stations are equipped with Cassegrain antennas 12—15 m in dia, whose swivel mount turns the antennas to within a few angular minutes of the satellite. The antenna direction is controlled by a programmed or automatic tracking system. Parametric amplifiers of the receiving circuits have a noise temperature of 80°K (when cooled). The ground-based transmitters are rated for 5 kW, the space-borne transmitter, for 40 W. The effective video-band (up to 5 Mc/s) ensures high-quality relay of TV programmes. The receiving stations of the *Orbita* system are connected with the local TV centres via radio relay lines; this permits broadcasting of central TV programmes over the entire territory of the USSR, including Far North, Siberia, Far East, and Central Asia.

ORBITAL ELEMENTS (Orbital parameters). Quantities that define the position of an orbit in space, its dimensions and shape, and also the position of a celestial body in orbit. The elements defining the position of the orbital plane and orientation of the orbit in this plane are introduced as follows. Let the motion of a celestial body be considered in the coordinate system P_0xyz (see Fig.) with origin in the centre of mass of the central body and with axes P_0x, P_0y, P_0z intersecting the celestial sphere at points X, Y, Z. We consider the plane of the great circle XY as fundamental and the point X as the fundamental point of this circle. We assume that the orbital plane intersects the celestial sphere in the great circle NAM, and the radius vector of the PERICENTRE at point A. Then the straight line $N'P_0N$ along which the orbital plane intersects the fundamental plane intersects the celestial sphere



is called the line of nodes. When a celestial body is in motion counterclockwise (looking from pole C), point N is called the ascending node, and point N' is the descending node. The arc XN, denoted by Ω, is termed the longitude of the ascending node or simply the longitude of the node. Angle MNY, denoted by i, at which the orbital plane intersects the fundamental plane, is called the inclination of the orbit; the inclination of the orbit is also the arc ZC of the great circle. The arc NA, denoted by ω, is known as the angular distance of the pericentre from the node. The quantities Ω, i and ω constitute the first group of orbital elements, the first two of which define the position of the orbital plane, the third defining the orientation of the orbit in that plane. The quantity i varies from 0 to π, Ω and ω from 0 to 2π. In the case of planetary motions, the plane of the ecliptic is most often taken as the fundamental plane, and the point of vernal equinox (First Point of Aries) as the fundamental point. In the theory of motion of artificial Earth satellites, the equatorial plane is frequently taken as the fundamental plane, and the point of vernal equinox as the fundamental point. The elements that define the dimensions and shape of the orbit are the latus rectum p and the eccentricity e. For an elliptic orbit these are the latus rectum and eccentricity of an ELLIPSE, for a hyperbolic orbit, the latus rectum and eccentricity of a HYPERBOLA, etc. The last, sixth, element is τ, the time of pericentre passage. This element defines the position of the celestial body in orbit at the initial time. The elements p, e, i, Ω, ω, τ are called Keplerian elements. They define the orbit irrespective of whether it is elliptic, parabolic, or hyperbolic. The sole difference is that for an elliptic orbit $e < 1$, for a parabolic orbit, $e = 1$, and for a hyperbolic orbit, $e > 1$. In literature one frequently encounters various modifications of the elements p, e, i, Ω, ω, τ. Thus, in the case of an elliptic orbit, in place of p we usually consider the semimajor axis a, sometimes the mean motion, and sometimes the orbital period T defined by the formula $T = 2\pi/n$. In parabolic or hyperbolic motions, in place of p use is made of the element q, called the PERIHELION DISTANCE or the PERIGEE DISTANCE, etc. The eccentricity e is occasionally replaced by an element called the angle of eccentricity and defined by the formula $e = \sin \varphi$. The element ω is frequently substituted by the element $\pi = \Omega + \omega$, which is called the longitude of the pericentre. The element τ is often replaced by the mean anomaly at epoch, $M_0 = n(t_0 - \tau)$, or the mean longitude at epoch. Here t_0 is the initial instant of time (epoch).

ORBITAL ORIENTATION. The orientation of an artificial satellite when its yaw axis is always directed to the centre of the celestial body (Sun, planet or planet satellite) around which the satellite flies, the pitch axis is normal to the plane of the orbit, whereas the roll axis

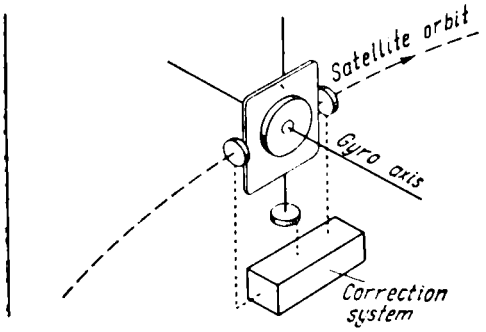


is in the orbital plane and in the event of a circular orbit coincides with the tangent to the orbit (see Fig.). Partial (uniaxial) orientation, when only one of the axes is oriented as described, is also employed. Orbit orientation is most frequently used for attitude control of meteorological and geophysical satellites, decelerating a satellite prior to re-entry, performing manoeuvres, etc.

ORBITAL VELOCITY. See FIRST COSMIC VELOCITY.

ORBIT ECCENTRICITY. See ORBITAL ELEMENTS.

ORBIT GYROSCOPE. A gyroscopic instrument used for fixed-space positioning of the orbital plane of a satellite. The principle of operation of the orbit gyroscope is based on the orderly rotation of the satellite occurring, e.g., when one of the satellite axes is oriented permanently to the local planet vertical. The most simple type of the orbit gyro consists of a two-frame gyroscope and an electrical or mechanical system of correction that brings the plane of rotation of the gyro in line with the orbital plane of the satellite (see Fig.); more complicate systems employing several gyros are feasible. Orbit gyro serves as the ORIENTATION SENSOR in the yaw and roll channels of satellite systems of orientation.



ORBIT PLOTTING. Selection of spacecraft orbits for the most effective accomplishment of the basic mission with minimum expenditure of technical facilities.

ORBITS OF METEOROLOCICAL SATELLITES. Near-earth orbits selected for meteorological satellites. These orbits are, as a rule, circular, which considerably facilitates interpretation of the measurements data. For world-wide survey of the Earth's atmosphere use is made of quasipolar circular orbits at heights of about 700—1000 km; when in such an orbit, a satellite passes over a given area on the Earth's surface once a day and always at the same local time. The problem of continuous observation of meteorological processes over large territories can be solved with the aid of meteorological satellites placed into a circular equatorial stationary orbit, when the period of revolution of the satellite coincides with the period of the Earth rotation about its axis, as a result, the satellite always hovers over the given region. The same result can be achieved by means of a LUNAR METEOROLOGICAL OBSERVATORY.

ORIENTATION OF DIRECTIONAL ANTENNAS. The aiming of spacecraft antennas towards ground stations of the satellite tracking or communication system by orienting the entire spacecraft or by employing swivelled antennas controlled by a follower mechanism. Orientation of directional antennas allows to reduce the output of the transmitters on board the spacecraft and to raise the level of the signal received by the ground stations; this promotes an increase in the transmission range and information carrying capacity of the system of radio communication.

ORIENTATION OF MAN IN SPACE. Orientation in space is highly important for man at all stages of flight in atmosphere or in space. It is brought about by physiological interaction between man's visual, vestibular, musculoarticular and tactile analyzers. By analyzing a great number of sensations, the cerebral cortex forms a picture (image) of the man's position (a body scheme, i.e., orientation of parts of the body in space, including clothing and footwear, and in the case of a pilot or spaceman, special equipment and space suit). This picture also incorporates the man's orientation in relation to the vehicle (relationship "man—vehicle", and in particular, "spaceman—spaceship") and, finally, orientation of man and vehicle in three-dimensional space in relation to outside reference marks (relationship "man—vehicle—free space", or, in particular, "spaceman—spaceship—interplanetary space"). The peculiarities of space flight (weightlessness, SENSORY DEPRIVATION, etc.) confront the spaceman with specific difficulties in orientation. However, special training (parachute jumping, free-fall aircraft flights, physical exercises) produces a favourable effect, and the spaceman's orientation in space flight conditions is good.

ORIENTATION OF SOLAR BATTERIES. The positioning of the working surface of spacecraft solar batteries perpendicular to the Sun rays. This position ensures maximum efficiency of the battery. It is attained by orienting the entire spacecraft or by hinging the batteries to the body of the spacecraft and turning them towards the Sun by means of special servomechanisms under the control of a SOLAR SENSOR.

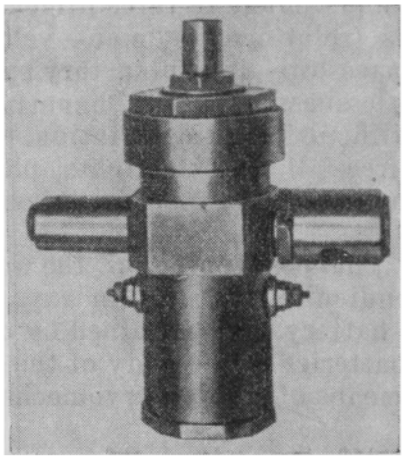
ORIENTATION OF SPACECRAFT. (1) The definite attitude of a spacecraft with respect to celestial bodies, lines of force of the magnetic or gravitational field, or other chosen directions in space. The orientation of a spacecraft varies with its mission; spacecraft intended for astronomical studies of the Sun, the Moon or stars are oriented to the respective celestial body; communications satellites equipped with directional antennas are oriented so that the latter are directed towards the ground stations of the system of radio communication; spacecraft carrying solar batteries are oriented so that the working surface of the battery faces the Sun, etc. In certain cases of spacecraft rendezvous, mutual orientation of the two spacecraft is required. Types of orientation are classified according to the number of oriented axes of the spacecraft (see SINGLE-AXIS ORIENTATION) and other characteristics. (2) Control of angular motion of a spacecraft in passive (unpowered) flight, i.e., communication to the spacecraft axes of a definite position with respect to pre-selected directions. The systems used for this purpose must oppose very slight disturbing moments acting on the spacecraft which makes it possible to utilize concepts and devices that are not suitable for other systems of control (see PASSIVE SYSTEM OF ORIENTATION, GRAVITATIONAL SYSTEM OF ORIENTATION INERTIAL ACTUATORS, ELECTROMAGNETIC ACTUATORS, REACTIVE GYRATING MASSES)

ORIENTATION SENSOR. A position pick-off used in an orientation system. These sensors are classified according to the methods of obtaining information bearing on the angular attitude of the spacecraft. The operation of orientation sensors of the 1st type is based on the use of celestial bodies (the Sun, planets), or the effect produced by their fields of force; orientation sensors of

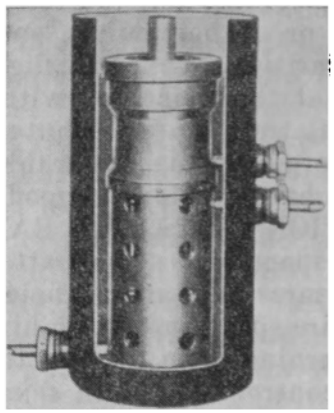
the 2nd type do not require any external source of information and may be totally isolated from outer space (e.g., ORBIT GYROSCOPE).

ORM

OPM (ORM). Abbreviation of the Russian words for "experimental rocket engine", serving as the designation of a family of experimental liquid-propellant engines with a thrust from 6 to 300 kg, that were created by the GDL. They fired various low- and high-boiling liquid oxidizers with liquid fuels. A series of liquid-propellant engines from *OPM-1* to *OPM-52* was developed in 1930—33. The *OPM-53* to *OPM-102* engines were designed in 1934—38



OPM liquid-propellant engine.



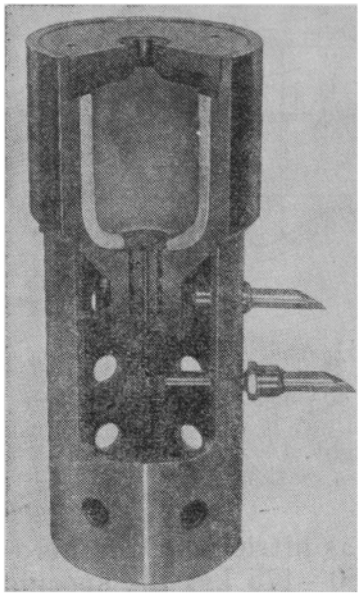
OPM-1, first liquid-propellant rocket engine built in the Soviet Union (Gas Dynamic Laboratory, 1930—31). It had a thrust of 20 kg.

by specialists from the GDL, who formed a special group at the RNII. The engines served for the development of the structural elements that ensured ignition, starting, and operation with the use of various liquid propellants, and for practical application on vehicles (e.g., *OPM-50*, *OPM-52*, *OPM-65*, etc.).

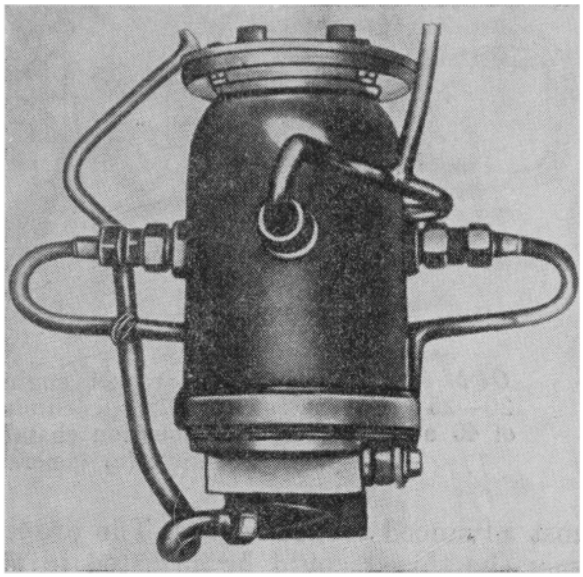
OPM was a liquid-propellant engine developed and tested (about 50 static firings) at the GDL in 1931. It fired monopropellant solutions of toluene or gasoline in nitrogen tetroxide. The engine had exchangeable nozzles, an instrument to measure maximum pressure, a safety valve, electrical cartridge ignitor, etc. It was used to study the conditions of safe work with a liquid monopropellant. It had a thrust of up to 6 kg.

OPM-1 was the Soviet first experimental liquid-propellant engine designed and built in 1930—31. It fired NITROGEN TETROXIDE and toluene. When tested with LOX and gasoline, it developed a thrust of up to 20 kg. The inside of the thrust chamber was copper-clad, it was cooled by a water-filled outer jacket. A set of exchangeable nozzles of 10, 15 and 20 mm internal dia was provided. Its 6 split injectors were fitted with non-return valves and filters. It was intended for short-term firings and comprised 93 parts.

OPM-9 was an experimental liquid-propellant engine designed for short-duration firings. It was tested in 1932 using LOX + gasoline propellant and ignited with a trotyl pyroxilin grain. Spray injectors were located in the head of the thrust chamber and directed along its centerline. The cylindrical combustion chamber of 90-mm internal dia and equal height was made



OPM-9 liquid-propellant engine.



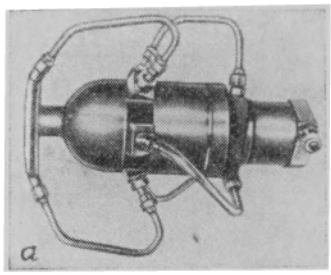
OPM-50 liquid-propellant engine on test bench.

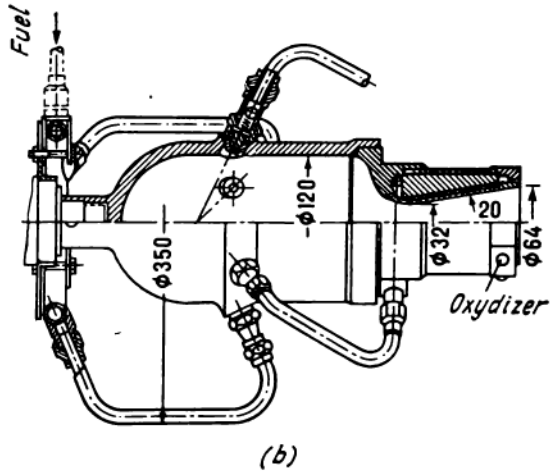
of steel and covered with a layer of ceramic thermal insulation 10 mm thick (zirconium dioxide or magnesium oxide with water glass). The nozzle, 15 mm in dia, had a plating of red copper 8 mm thick.

OPM-50 was a pilot-type liquid-propellant engine capable of 150 kg of thrust. It burnt nitric acid and kerosene and had a chemical ignition system. It was intended for the *05* rocket designed in the GIRD. The engine passed the acceptance tests in 1933. Its design permitted several test firings to be carried out. The steel combustion chamber shaped as a cylinder of 120-mm internal dia was cooled by fuel film, the cover of the chamber and the conical nozzle with spiral ribs were regeneratively cooled with the acid. The nozzle throat section had the dia of 23 mm. 4 atomizing injectors with non-return valves served for propellant admission into the thrust chamber.

OPM-52. This liquid-propellant engine developed by the GDL was the most powerful rocket engine in the 1930s. It was formally tested in 1933. It developed a thrust of 250—300 kg firing nitric acid and kerosene and had a chemical igniter. It was intended for the *РЛА-1* and *РЛА-2* ground-to-air rockets and a naval torpedo then under development in the GDL. The steel cylindrical combustion chamber had a spherical head and was cooled with a fuel film; the acid was used for regenerative cooling of the cover and the nozzle with spiral ribs. 6 atomizing injectors with non-return valves were used.

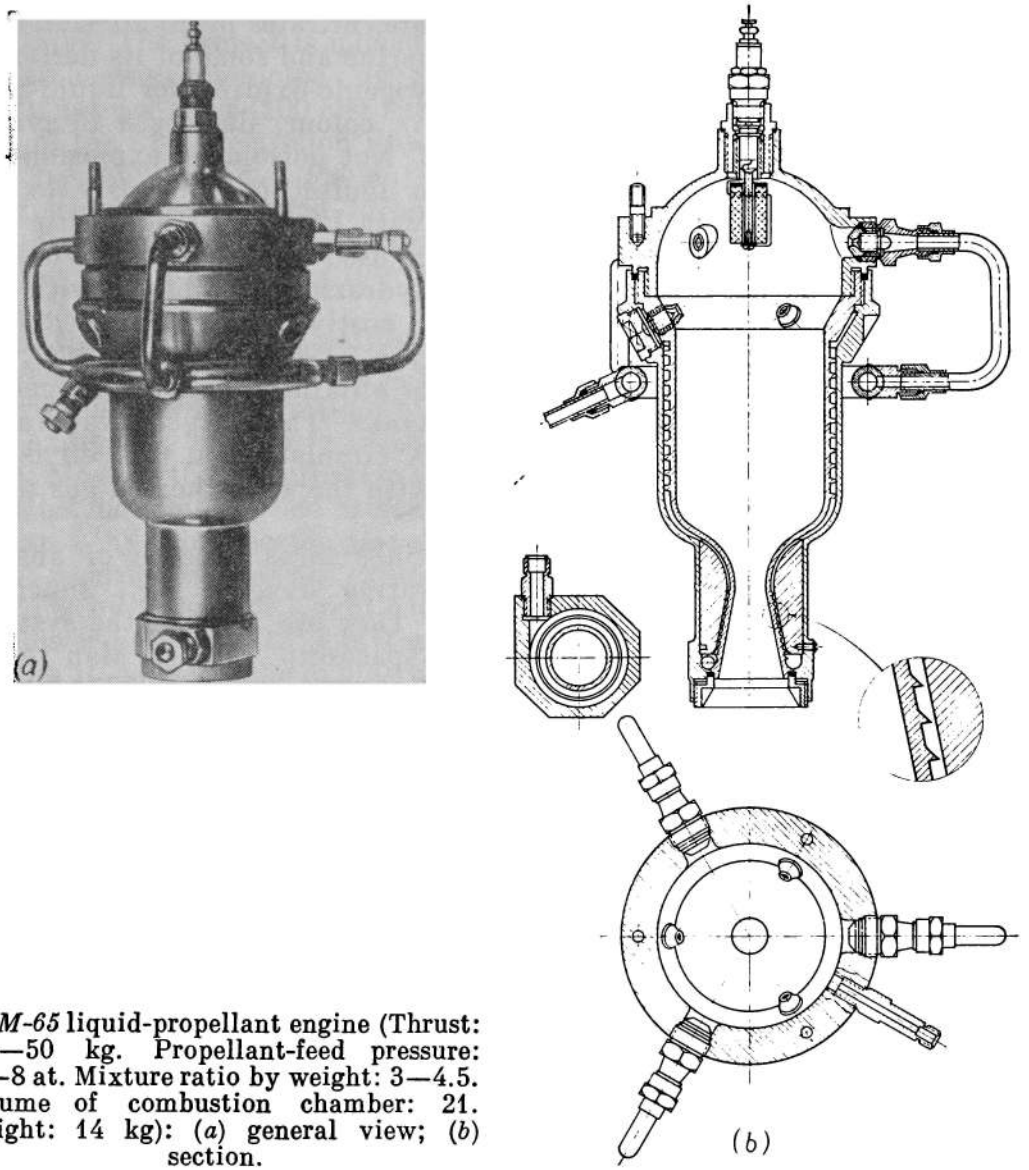
OPM-65 was a liquid-propellant engine developed at the RNII by specialists from the GDL. It was formally tested in 1936. At that time, it was the most advanced rocket engine. The propellant used was nitric acid and kerosene; the thrust could be adjusted in the range of 50—175 kg; the specific impulse was 210—215 s; the engine was started manually or automatically; the ignition of the cartridge-type, with an electric fuse, was equipped with signalization; the engine withstood repeated (up to 50) firings and an accrued operating time of up to 30 min. The pressure in the combustion chamber was 25 at ab. The steel combustion chamber of 100-mm internal dia and the 20° conical nozzle with throat section dia of 23 mm had spiral ribs for regenerative cooling with the oxidizer. 3 atomizing injectors for each propellant component were provided. 30 ground firings of *OPM-65* were conducted in 1937—38 during testings of the *PП-318-1* rocket glider designed by S. P. Korolev. In 1940 the pilot V. P. Fyodorov accomplished a flight on this rocket glider powered by a modification of the *OPM-65*. The *212* winged rocket of Korolev design underwent 13 ground firings in 1937—38 and two flight tests in 1939, propelled by *OPM-65*. See Fig., p. 293.





OPM-52 liquid-propellant rocket engine (pressure in combustion chamber 20—25 atm; excess-of-oxidizer coefficient 1.08; propellant fed by pressure of 40 atm; volume of combustion chamber, 2.23 l; weight, 14.5 kg; specific impulse, 210 sec): (*a*) general view; (*b*) cross section.

OSCULATING ELEMENTS. ORBITAL ELEMENTS, regarded as functions of time, in terms of which the coordinates and component velocities in disturbed motion are expressed by the same formulas as in undisturbed motion. Osculating elements are very convenient variables in the study of disturbed motion. If there were no perturbing forces, the osculating elements would be constant and the orbit of a celestial body would be a conic section, e.g., an invariable ellipse. Because of a perturbing force, the elements will vary with time and the ellipse will alter its shape and its position in space. An osculating ellipse has the property that at each instant the tangent to it at the point at which a moving celestial body lies will coincide with the tangent to the true orbit at that point.



OPM-65 liquid-propellant engine (Thrust: 175—50 kg. Propellant-feed pressure: 35—8 at. Mixture ratio by weight: 3—4.5. Volume of combustion chamber: 21. Weight: 14 kg): (*a*) general view; (*b*) section.

OXIDES OF NITROGEN. Oxidizers for liquid propellant rocket engines, used independently or in the form of solutions in nitric acid and other oxidizers. Extensive use is made of nitrogen tetroxide.

OXIDIZER. A component of rocket propellants serving for the oxidation of the fuels in rocket engines. Since the consumption of the oxidizer is usually from 2 to 4 times greater than that of the fuel, and the properties of the oxidizer used vary to a great extent, it is the type of oxidizer that chiefly determines the characteristics of the rocket propellant and the rocket engine itself. Liquid oxidizers most frequently used are: LOX, nitric acid, nitrogen tetroxide, concentrated hydrogen peroxide. The solid oxidizers used are: ammo-

nium and potassium chlorate and perchlorate, nitrates of alkali metals, etc. In the future use may be made of liquid fluorine and some of its derivatives.

OXYGEN, liquid, O_2. A highly effective cryogenic oxidizer for liquid-propellant engines. A low-boiling liquid, blue in colour; density 1.14 g/cm^3 at —183°C; b.p. —182.98°C; m.p. —218.76°C. Not poisonous, explosion-proof, but inflammable. Ordinarily fuels do not ignite spontaneously in LOX. Structural materials that come in contact with LOX must be plastic at low temperatures and flame-proof. It is widely used with kerosene, sometimes with ammonia, unsymmetrical dimethyl hydrazine, as well as with liquid hydrogen; has been used with alcohols. Not costly and in unlimited supply; is obtained from the air. Proposed by K. E. Tsiolkovsky in 1903.

OXYGEN EVAPORATOR. An apparatus for obtaining gaseous oxygen from LOX for pressurization of LOX supply tanks. The oxygen evaporator is, essentially, a heat exchanger wherein LOX circulating in the coil is transformed into gas due to the heat exchange with the air or heated gas washing the coil.

OXYGEN-GENERATING SUBSTANCES. Substances capable of absorbing moisture and carbon dioxide and liberating oxygen, e.g., superoxides of alkali metals (KO_2, NaO_2, or LiO_2). They are used in the systems of BIOLOGICAL AIR REGENERATION in sealed spaceship cabins. Man excretes an average of 40—50 g/h of water and consumes about 25 l/h of oxygen; to obtain this amount of oxygen, only 13.2 g/h of water are necessary. Consequently, the LSS is provided with additional absorbers to ensure removal of excess moisture and carbon dioxide from the air, and keep the oxygen concentration within the permissible maximum. By using oxygen-generating substances with a higher oxygen content, e.g., ozonides of alkali metals, the weight of the system can be further reduced. LSS employing oxygen-generating substances are intended for short-duration flights lasting 10—15 days. Such systems were used in the *Vostok* and *Voskhod* spaceships. Man also excretes oxygen-containing substances such as carbon dioxide and water; their oxygen content exceeds man's requirements 3.5 times. A LSS capable of oxygen recovery from carbon dioxide and water and performing water purification of noxious admixtures will practically be able to ensure a complete water and oxygen recycling. The weight and size of such a life support system will not depend on flight duration. Such physico-chemical life support systems are intended for air regeneration in spaceship cabins during sustained space flights.

OXYGEN, MEDICAL-GRADE. Oxygen obtained by means of water electrolysis. It can be used for respiration and, in particular, for BIOLOGICAL AIR REGENERATION in the spaceship's sealed cabin. Medical-grade oxygen should not contain noxious admixtures, such as carbon monoxide, gaseous acids and bases, ozone, etc., nor should it have colour or odour. Medical-grade oxygen should contain not less than 98.5% oxygen, and 0.5—1.5% argon and nitrogen, and a maximum moisture content of 0.07 g/m^3. Liquid medical-grade oxygen should not contain water crystals, mechanical admixtures and oil.

OZMA PROJECT. A programme for the search of signals of extraterrestrial civilizations, carried out in May—July, 1960, by the National Radio Astro-

nomy Observatory at Green Bank, W. Va., (USA) under the leadership of F. D. Drake. The project is named after the fairy queen of the country of Oz. The search was conducted by a 27-metre RADIO TELESCOPE with a high-stability narrow-band (100 c/s) superheterodyne receiver on a frequency close to that of the 21-cm emission line of atomic hydrogen (1420.4 Mc/s) in a frequency band of 400 kc/s. The antenna was focused on the stars τ Ceti and ε Eridani which are believed to have planetary systems. The apparatus permitted detecting artificial signals with a frequency band less than 100 Hz and power output exceeding 10^{13} W. No signals of an artificial character were received.

OZONE, liquid O_3. A low-boiling, pungent liquid, violet in colour; density 1.35 g/cm^3 at —112°C; m.p. —192.5°C, b.p. —111.9°C. Very poisonous; initiates spontaneous ignition of many liquid and solid fuels; unstable, highly explosive, especially in the gaseous state (no reliable stabilizers are known). Most of the structural materials that are corrosion resistant in LOX also withstand liquid ozone attack. Liquid ozone is considerably more effective than LOX (the specific impulse and density obtained are greater), but it is not used because of the explosion hazard. Solutions in LOX, containing up to 24% by weight of liquid ozone, do not explode; however, evaporation of the lower-boiling LOX and the resulting liquid overrich in liquid ozone can make it dangerously explosive. Proposed as an oxidizer for liquid-propellant engines by K. E. Tsiolkovsky in 1914; solutions of liquid ozone in LOX have been tested in GDL (1930).

OZONIZATION. The use of ozone for disinfection of spaceship (cabin atmosphere, drinking water, etc.) as well as for mineralization of the metabolic by-products in the LSS. Oxygen is converted to ozone in ozonizers by the action of a silent electric discharge or the short waves of solar irradiation.

P

PARABOLA. A 2nd-degree curve, the locus of points equidistant from a given point (focus) and a given straight line (directrix). See CONIC SECTIONS.

PARABOLIC MOTION. Motion along a PARABOLA. Occurs in the PROBLEM OF TWO BODIES. It is frequently used as a 1st approximation in studies of the motion of certain comets.

PARABOLIC VELOCITY. The velocity of the relative motion of two bodies mutually attracting in accordance with the law of universal gravitation, in which the resulting orbit is parabolic. Parabolic velocity is the least relative velocity of the two attracting bodies, as a result of which they can ultimately move apart to an infinite distance. At velocities less than parabolic, the mutual recession is limited and the relative motion occurs in an ellipse; if the velocity is greater than parabolic, the resulting motion is hyperbolic. At the surface of the Earth, parabolic velocity is called the SECOND COSMIC VELOCITY.

PARACHUTE JUMP. A means of landing the crew during spaceship return (see EJECTION). Parachute jumps are also employed as a method of training to improve the spacemen's ORIENTATION in space, studying their emotional and vegetative excitability, and developing volitional abilities necessary to suppress excessive emotional tension.

PARACHUTE SYSTEM. Several parachutes, deployed successively and called, respectively, pilot, deceleration, and recovery parachutes. With this system deceleration takes place in steps and g-force is kept below the critical level when a spacecraft re-enters the atmosphere of the Earth (or another planet). Parachute system operation is initiated and cycled by space-borne automatic control.

PARADOX OF TWINS. An illustration of the well-known CLOCK PARADOX of the special theory of relativity, which consists in that the indications of two originally synchronized clocks do not coincide if one of the clocks is at rest and the other moves over a closed path. Accordingly, when two twins meet after one of them returns from a space trip, their ages will be different, the traveller being younger due to the slowing down of time in a moving system. Paradox of twins provides the theoretical possibility of interstellar flight within the lifetime of a single person.

PARALLEL APPROACH. An approach of spacecraft during which the line joining the two spacecraft remains parallel to itself while moving in space. From the viewpoint of power consumption parallel approach is less economical than approach along a free-flight trajectory, but is technologically more feasible.

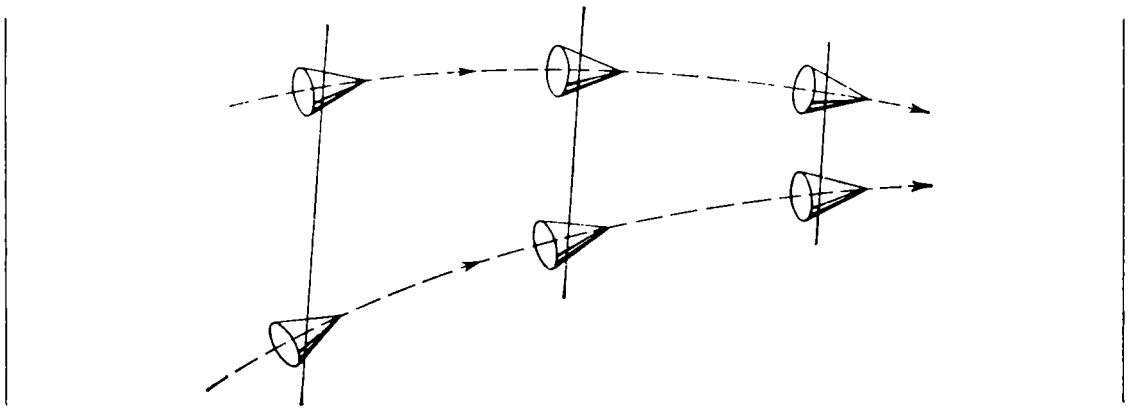
PARALLEL OF DECLINATION. Any small circle of the CELESTIAL SPHERE whose plane is parallel to the plane of the CELESTIAL EQUATOR and perpendicular to the CELESTIAL AXIS.

PARAMETRIC AMPLIFIER. An amplifier having a very low noise level, wherein the electrical oscillations generated in an oscillatory circuit tuned in to the received frequency are amplified by making use of the energy generated by another "pumping" oscillator of a different frequency that periodically varies the parameters (capacitance or inductance) of the oscillatory circuit. Parametric amplifiers with a variable capacitance of the oscillatory-circuit semiconductor diode are employed in ground stations of systems

of tracking of, and radio communication with, Earth satellites, spaceships, or automatic interplanetary stations. The NOISE TEMPERATURE of parametric amplifiers (cooled to the temperature of liquid helium) equals 20°—30°K and their gain factor is about 40 dB.

PARSEC. See ASTRONOMICAL UNITS.

PASSIVE COMMUNICATIONS SATELLITE. An Earth satellite that serves as a PASSIVE RELAY STATION of a system of space communication. Passive communications satellites for omni-directional diffusion of the energy



of radio waves are usually plastic balloons up to 40 m in dia having an aluminium coating. Directional reflection can be attained by the employment of baloons in the form of a sphere with a checkerboard, flat-spiral or another structure, or of a barrel, saucer, or other shape satellite.

PASSIVE PHASE of flight trajectory. That part of the flight trajectory along which the motion proceeds with cut-off rocket engine. Begins at the moment of killing the engines thrust. The motion along this phase of the trajectory depends upon the effect of natural forces: the attraction of the Earth, Sun, Moon, planets, the atmospheric drag, etc. (see also POWERED-FLIGHT PHASE).

PASSIVE RELAY STATION. An electrically conducting medium or mechanical structure capable of diffusing or directionally reflecting the energy of radio signals. It serves as an intermediate station in radio communication lines. Passive relaying is brought about by the employment of a PASSIVE COMMUNICATIONS SATELLITE, a CLOUD OF IONIZED PARTICLES, a BAND OF NEEDLES, the Moon surface, etc.

PASSIVE SYSTEM OF ORIENTATION. A system of spacecraft orientation, utilizing external forces, which makes unnecessary the consumption of power carried by the spacecraft. GRAVITATIONAL SYSTEMS OF ORIENTATION are the most frequently used. Passive systems of orientation making use of the forces produced by the pressure of sunlight, solar corpuscular radiation (SOLAR WIND), aerodynamic forces arising in flight of the spacecraft through the upper rarefied atmosphere of a planet and an interaction of the spacecraft magnetic masses with an external magnetic field are also conceivable. The main advantage of passive systems of orientation is that they do not consume power and have a practically unlimited life. On the

other hand, the resistance of such systems against DISTURBING MOMENTS is low since their operation is based on the utilization of very weak forces.

PAYLOAD. The rocket-borne compartments and equipment intended for direct accomplishment of the rocket mission. In a combat missile, it is a warhead containing the explosive charge and its control gear. In a space rocket, it is a spacecraft.

PEENEMÜNDE. A rocket testing range set up in Germany in 1937. The first liquid-propellant long-range rockets *V-2* (*A-4*) were fired from Peenemünde in 1942. In 1945 the range was dismantled; its technical equipment, as well as a group of scientists and engineers headed by W. von BRAUN, were taken to the USA.

PENTABORANE, B_5H_9. A high-boiling fuel for liquid-propellant engines. A colourless, mobile liquid with an unpleasant odour; density 0.63 g/cm³ at 18°C; m.p. —46.9°C; b.p. 58°C. Extremely poisonous. Thermostability limited. Stable at ordinary temperatures. Ignites spontaneously in the air; means for raising the spontaneous ignition temperature are known. Does not attack structural metals. Dissolves in hydrocarbons. Forms a highly effective propellant with high-concentration hydrogen peroxide. Pentaborane is being studied as a prospective fuel for rocket engines.

PERCHLORIC ACID, $HClO_4$. A high-boiling oxidizer for liquid-propellant engines. A colourless, fuming (in air), highly hygroscopic liquid; density 1.77 g/cm³ at 20°C; m.p. —112°C, b.p. 110°C. Poisonous, aggressive; many organic compounds ignite spontaneously on contact with perchloric acid. Highly concentrated perchloric acid is unstable and explosive (stabilizers are known). The pure acid is non-corrosive, but its decomposition products are. As to the specific impulse produced, propellants on the basis of perchloric acid do not differ from those on the basis of nitrogen tetroxide and tetranitromethane. The principal advantages are the wide range of temperatures at which the acid remains liquid and the higher density of the propellants formed. The use of perchloric acid is hindered by its unsatisfactory stability. Proposed as oxidizer for rocket engines in GDL (1930).

PERELMAN, Yakov Isidorovich (1882—1942). Soviet scientist and popularizer of the ideas of reactive motion and interplanetary travel. Graduated from the St. Petersburg Institute of Forestry in 1909. From 1919, taught physics. The initiator of the law on advancing the clock one hour in Russia for the purpose of saving fuel on lighting (1917). The author of many popular science books, the best known being *Zanimatelnaya Fisika* (*Physics for Entertainment*, 2 vol., 1st ed. 1913—16, 17th ed. 1965), *Zanimatelnaya Geometriya* (*Geometry for Entertainment*, 1st ed. 1935, 11th ed. 1959), *Mezhplanetnye Puteshestviya* (*Interplanetary Travel*, 1st ed. 1915, 10th ed. 1935). Took an active part in the work of LenGIRD. A crater on the far side of the Moon has been named in his honour.

PERICENTRE. The point in the orbit of a celestial body closest to the central body. See PERIGEE, PERIHELION, PERILUNE.

PERIGEE. The point at which the Moon or an artificial satellite or any other celestial body in its orbit is closest to the Earth centre.

PERIGEE DISTANCE. The distance between the perigee of the orbit of a celestial body and the centre of the Earth.

PERIHELION. The point closest to the Sun in the orbit of a planet, comet or other celestial body whose motion is considered in reference to the Sun.

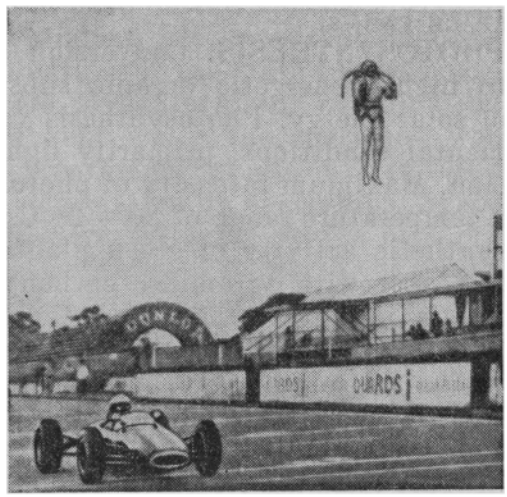
PERIHELION DISTANCE. The distance between the perihelion of the orbit of a celestial body and the centre of the Sun.

PERILUNE. The point closest to the Moon in the orbit of a lunar satellite or other celestial body whose motion is considered in reference to the Moon.

PERIODIC MOTION. Motion of a body in which the body's position in space and its velocity recur at certain equal intervals of time. More precisely, if for time t and time $t + T$ the coordinates of a body and its component velocities assume the same values, the motion is periodic with a period equal to T. An instance of periodic motion is the elliptical motion in the PROBLEM OF TWO BODIES.

PERIOD OF REVOLUTION. The time in which a celestial body completes a full circuit about a central body.

PERSONAL ROCKET ENGINE. A low-thrust small-size rocket engine for spaceman extravehicular propulsion. One type is manipulated by the spaceman to obtain the required direction of thrust; the other is a backpack type in which the spaceman switches the propellant supply to one of several differently oriented nozzles to move in the desired direction. Compressed gas or a SINGLE-COMPONENT MONOPROPELLANT is usually the working fluid.



Race between a car and a man carried by a personal rocket engine (Great Britain).

PETROPAVLOVSKY, Boris Sergeyevich (1898—1933). Soviet artillery engineer, designer of rocket fired by slow-burning smokeless powder. In 1929 he began working at the GAS DYNAMICS LABORATORY and headed its work in 1930—1932. Petropavlovsky was the main collaborator in designing the rockets for *Katyusha* mortars of World War II fame. A crater on the far side of the Moon bears his name.

Photo-electric cell

PHOTOELECTRIC CELL. Semiconductor capable of converting solar light energy to electric energy; widely used in spacecraft electric power systems. The cell usually comprises a silicon wafer cut from an ultra-pure monocrystal of silicon and specially treated to produce two regions of conductivity within it, namely, an *n*-type and a *p*-type. When solar light falls on such a cell, it sets up a difference of potentials between the two regions.

PHOTON ROCKET ENGINE (quantum or laser engine). A hypothetical rocket engine in which thrust is created by a flow of quanta of light, or photons. It has the highest specific impulse since the velocity of flow of photons is the greatest possible, i.e., the speed of light. It can be applied in sustained long-distance space travel, e.g., interstellar flight.

PHOTOPERIODISM. Daily duration of light required by a plant. Plants are divided into short-day (requiring no more than 12 h of light a day); long-day (requiring more than 12 h of light a day) and day neutral, in which the development of the generative organs does not depend on the duration of light. Photoperiodism must be considered when selecting plants for SPACE FARMS.

PHOTOSYNTHESIS. Conversion of atmospheric carbon dioxide and water to highly energetic organic substances, by green plants under the action of solar energy. Photosynthesis varies in intensity and depends on environmental conditions, primarily light intensity and carbon dioxide concentration. Maximum intensity of photosynthesis is observed in most plants within a temperature range of 20°—28°C. During sustained space flights, the photosynthetic activity of green plants can provide man not only with oxygen, but also with vitamins, carbohydrates, proteins and fats. Cultivation of plants in spaceships and interplanetary stations simplifies water supply.

PHOTOSYNTHETIC REACTOR (gas exchanger). A closed vessel for cultivation of micro-algae, where photosynthesis takes place in a spaceship LSS. A spaceship's photosynthetic reactor must conform to flight conditions and be simple to operate, highly reliable, resist to space flight effects (accelerations, vibration, etc.), be economical, light in weight and small in dimensions with the largest possible functional area and productivity. It must be able to function in specific space flight conditions (weightlessness or artificial gravitation, possible exposure to various types of radiation, complicated heat exchange, possible fall of ambient pressure, etc.).

PHYSICO-CHEMICAL MINERALIZATION. A group of methods for mineralization of human and other wastes of the LSS BIOCOMPLEX, based on acceleration of oxidation of organic material by physical factors, such as temperature and pressure. Changes in the rate of chemical reactions are determined by the Le Chatelier principle; this means that alteration of one condition (e.g., concentration of reactants, temperature, or pressure) in a system in a state of chemical equilibrium shifts the latter towards reactions which strive to restore the former conditions (i.e., the former concentration, temperature, or pressure). Physico-chemical methods may be widely used in a LSS for mineralization of biological wastes by THERMAL OXIDATION, WET OXIDATION, or catalytic oxidation.

PHYSIOLOGICAL INVESTIGATION, extraterrestrial. Electrodes and sensors for continuous medical monitoring in space flight are secured to the space-

man's body for a long period without causing unpleasant sensation or interfering with his work. Investigations are made mainly by electrocardiography, seismocardiography and pneumography. Through a special chest girdle the electrodes and sensors are secured to the sites selected for fixing electrocardiograph electrodes; in this way, precise information is obtained over a long period during rest and movement. In most cases the electrodes are fixed to the right and the left sides, along the median auxiliary line at the level of the 5th intercostal space.

Pitch, yaw, roll

Seismocardiography is a new method used in studying the heart contractive activity during flight; the sensor detects the chest wall vibrations caused by the heart activity. Pneumography is done by a carbon-type sensor mounted in the chest girdle. Used also on the *Vostok* spaceships were electro-encephalography (for studying the state of the central nervous system), electro-oculography (for studying oculogyration to detect symptoms of vestibular apparatus irritation), and dermatogalvanic tests (to evaluate the state of the vegetative nervous system).

Detachable sensors and electrodes were first used on the *Voskhod* spaceship to carry out a special program of medical studies. Electro-encephalograms, electro-oculograms, dynamograms (for evaluation of the state of the neuromuscular system) and handwriting tests (to evaluate motor coordination) were registered in sequence; records were kept while the spacemen were carrying out planned functional tests. Such programmed studies will in future be the main means of obtaining scientific information on spaceships. Spaceborne computers will be used to process and evaluate the results of a programmed study immediately, and the data transmitted to Earth, or delivered to the crew physician. The development of methods of physiological investigation of test animals in space flight is of great importance. The 2nd and 3rd Soviet satellite-spacecraft, called "flying laboratories", used some 10 different techniques to study the functioning of the cardiovascular, respiratory, thermoregulating and neuromuscular systems of dogs. In the experiment on the *Cosmos-110* satellite physiological examination of animals was fully automated; the programmes included artificial stimulation of receptor zones and administration of pharmacologically active agents.

PILOT-COSMONAUT OF THE USSR. The honorary title which is bestowed by the Soviet Government on cosmonauts for successful execution of space flight missions.

PITCH ANGLE PROGRAMME. A pre-computed and carefully controlled variation of the angle between the longitudinal axis of a launch vehicle and the plane of the local horizon during the POWERED FLIGHT PHASE. This angle changes within the range from 90° (at starting phase of flight) to values approaching 0° (at end of powered phase).

PITCH, YAW, ROLL. (1) The angular coordinates of an artificial satellite having an orbital orientation. The pitch is the angular declination of one of the axes of the satellite from the plane perpendicular to the line passing through the central body; the yaw is the angular declination of the same axis from the plane of the orbit; the roll is equal to the angular displacement of the two other axes of the satellite from their respective design positions. These terms are sometimes used arbitrarily to define the angular coordinates

of spacecraft employing other types or orientation. (2) The angular coordinates of a launch vehicle. In this case, the pitch is equal to the angle between the longitudinal axis of the launch vehicle and the plane of the local horizon, the yaw is the declination of the longitudinal axis from the plane of the trajectory of the launch vehicle, and the roll is the turn of the launch vehicle about its longitudinal axis. The pitch, yaw and roll channels are channels (circuits) of the system of satellite orientation or the system of angular stabilization of the launch vehicle that control the respective angular coordinates and keep them within specified limits.

PIVOT MECHANISM. A mechanism for turning the swivelling portion of a launcher through a required angle during azimuth alignment of the launch vehicle. The basic elements of the pivot mechanism are an internal gear, sun gear, gear-box, and drive. Pivot mechanisms employ manual, motor or selsyn drives, the latter being employed in automatic azimuth alignment systems. In case of motor drives, besides an electric or hydraulic motor a stand-by manual drive is provided.

PLANET. See SOLAR SYSTEM.

PLANETARY EXPEDITION. A manned spaceship flight to a planet, landing on its surface, and subsequent return to the Earth. Planetary expeditions present complex scientific, and engineering problems. Planetary expeditions to Mars will become technically possible in the relatively near future.

PLANETOGRAPHY. A branch of science studying the nature of the planets of the solar system. With respect to its aims and content, planetography is the cosmic counterpart of physical geography.

PLANETOIDS. See MINOR PLANETS.

PLANETOLOGY. The study of planets; that branch of knowledge which embraces information on the physical properties, chemical composition, and internal structure of both the inner and the outer planets. Planetology in a narrower sense makes morphotectonic studies of the planets of the inner group and their satellites. When studying the composition and structure of matter which makes up the surfaces of the planets, wide use is made of astrophysical methods, such as the polarization, albedo measurement, colorimetric, luminescent, and radio-astronomic methods.

PLASMA. Ionized gas with a sufficiently high concentration of electrically charged particles, possessing quasi-neutral properties, i.e., containing an equal quantity of positive and negative charges. Plasma is produced on intensive heating, in an electrical discharge, etc. It is the working fluid of electromagnetic rocket engines and plays an important role in thermo-nuclear research. Plasma is the basic form of existence of substances in outer space (stars, nebulae).

PLASMA ROCKET ENGINE. See ELECTROMAGNETIC ROCKET ENGINE.

PLUTO. The most distant known planet in the solar system and the 9th in the order of distance to the Sun. The mean distance from the Sun is 39.75 A.U. (5,947,000,000 km), Pluto's orbit has an eccentricity of 0.253 and an inclination of orbital plane to ecliptic of 17°8′, both larger than those of the major planets. The sidereal revolution period is 247.7 years and the mean orbital velocity, 4.7 km/s. Pluto is yellower than the Sun, its albedo

being 0.14. The period of light variations is 6.39 days which is equal to the period of its rotation. The temperature at the sub-solar point is 60°K. No investigations to detect the atmosphere of Pluto have been carried out. Pluto's mass as derived from the perturbations of Neptune is $5.5 \cdot 10^{27}$ g which is 0.925 of that of the Earth. The disk of Pluto cannot be observed through telescopes, its dia estimated from the coverings of stars is in the range of 6.8—2 thou km (the most probable dia of 5.5 thou. km, in conjunction with the estimated mass, would suggest a mean density of 50 g/cm^3 which is the highest figure for planets of medium density). If the density of Pluto is assumed to be normal, then its mass would be small and strong perturbations of Neptune's orbit would lead to a suspicion that some gigantic trans-Plutonian planet remains to be found, but the chances of finding it are extremely slight. The estimations for gravitational acceleration and the 2nd cosmic velocity are not known for Pluto. Pluto has no known satellite.

PNEUMATIC COUPLING UNIT. A combination of pneumatic couplings accommodated in a common housing and installed in the pneumatic system of a launching site or a maintenance area. Joined and sealed with its counterpart on the launch vehicle, it connects the on-board and ground pneumatic systems ensuring supply of compressed gases to the launch vehicle and control of pressure in different compartments of the vehicle. The number of gas lines brought to the launch vehicle may run to several tens, therefore the pneumatic couplings of these lines are sometimes combined in a number of pneumatic coupling units. Special mating mechanisms are used for joining the ground-end pneumatic coupling units with their vehicle counterparts during pre-launch preparation, and for separating them during the blast-off.

PNEUMATIC FITTINGS. The devices of a lanch complex intended for adjustment, cut-off, and checkout of compressed gas supply to the launch vehicle and other consumers. The fittings fall into valves, hand-operated valves, pressure reducing valves, filters, pressure warning units, pressure gauges, pressure vacuum gauges, pressure switches, sensors of remote-reading pressure gauges, and pipeline connecting elements built into compressed air mains. The valves in pneumatic systems function similarly to those in hydraulic systems (see PROPELLANT LOADING FITTINGS). The reducing valves are designed for reducing gas pressure (by throttling) and for maintaining its magnitude invariable when the compressed gas is supplied from high-pressure bottles. They incorporate a valve controlled by an elastic diaphragm or sylphon assembly whose movement is actuated either mechanically (by means of a press screw or a spring) or pneumatically (by the control gas pressure); a control force variation displaces the valve relative to its seat and changes the gas pressure reduction ratio. The filters serve to remove moisture and mechanical impurities from gas (see FILTRATION OF GASES, COMPRESSOR PLANT). The pressure warning units are transducers that operate at a definite level of pressure to supply an electrical signal to an indicating instrument or to the automatic control system, thus giving a warning that a prescribed pressure has been attained. They incorporate a sensitive diaphragm and an electric converter of either contact or induction type. On

being actuated by gas pressure the pressure switches automatically close the electric circuit controlled by them; the actuating elements of pressure switches are mechanical contacts, whereas the command element (the controller) is a pressure sensitive diaphragm. The sensors of remote-reading pressure gauges are pressure transducers with either resistance or inductance converters that produce electrical signals proportional to the pressure value and send these signals to an indicator graduated in pressure units.

PNEUMATIC PANELS OF PROPELLANT-LOADING SYSTEM. Panels with pneumatic fittings for remote control of filling the launch vehicle with propellant and compressed gases, and for checking the pneudraulic system of the launch vehicle in the space centre. The fittings installed on the pneumatic panels include cut-off valves, gas pressure reducers, electric actuated pneumatic valves, and pressure gauges. The pneumatic panels are classified into launching, propellant-loading, drainage and auxiliary types. The launching panel is designed to deliver the actuating gas to various pneumatic valves of the rocket engine and the launch vehicle tanks, to fill the vehicle's pneumatic bottles with compressed gas, to preliminarily pressurize the propellant tanks, to deliver chilled air for cooling the instrument compartment and hot air for heating the engine bay of the launch vehicle. The propellant-loading panel supplies actuating gas to electric actuated pneumatic valves and actuators of the hydraulic fittings while the launch vehicle is being filled with propellants. The drainage panel supplies actuating gas to the pneumatic actuating elements of hydraulic fittings taking part in the operations of propellant drainage from vehicle tanks and propellant-loading lines. The auxiliary panel is designed for controlling the pressurization of the propellant tanks and forcing the propellant out of the terminal and drainage tanks.

PNEUMATIC PANELS OF RECEIVER ROOM. A complex of panels controlling the reception of compressed gases from the gas supply station and their distribution to consumers. The main pneumatic panels are nitrogen and air charging panels, air and nitrogen supply panels, actuating air panel, and a number of nitrogen and air process panels. The charging panels are designed for filling the receiver cylinders with compressed gas, draining of compressed gas, and checking its humidity in the charging lines and cylinders. The supply panels deliver high-pressure compressed gas to the actuating air panel and the process panel. The reducers of the actuating air panel lower the air pressure to the required level and deliver the air to the automation panel located in the fuel terminal and the oxidizer terminal buildings. The process panels are intended for receiving high-pressure gas from the receiver room cylinders, reducing its pressure to the required level, and delivering it to the launching, propellant-loading, drainage, and auxiliary pneumatic panels.

PNEUMATIC VALVE UNIT. A group of pneumatic valves mounted on a common panel and designed for centralized control of a system or part thereof.

POLARIZATION OF RADIO WAVES. Depends on the type of antenna used for transmission and is determined by the position of the electric field vector. In the case of linear polarization and propagation of radio waves in open space, the vector of the electric field remains permanently parallel to itself;

in the case of circular polarization, it rotates with the frequency of the radio wave, retaining a constant magnitude, and, in the case of elliptical polarization, it rotates as in circular polarization but varies simultaneously in magnitude. The plane of polarization rotates when the radio waves propagate in the magnetic field of the ionosphere, or when they are emitted from a rotating satellite, a spaceship or an automatic interplanetary station. This rotation is liable to cause fading of the signals in the case of their reception by a linear-polarized antenna, or may weaken them to 3 dB in the case of reception by a circular-polarized antenna.

POLYOT. Name of the first manoeuvrable Earth satellites to go into orbit. These were Soviet satellites fitted with special controls and a rocket power-plant which permitted them to change, in flight, the height and inclination of their orbits. Besides this, they carried a set of scientific instruments, a telemetry system, and radio transmitters. *Polyot-1* was launched on November 1, 1963, and had an initial orbit with a perigee of 339 km and an apogee of 592 km. After several manoeuvres, it was changed over to an orbit having an apogee of 1437 km. *Polyot-2* went into orbit on April 12, 1964. Several in-orbit manoeuvres changed the perigee from 310 to 236 km, the apogee from 500 to 465 km, and the inclination from 58 to 60°.

POPOVICH, Pavel Romanovich (born 1930, Uzino village, Kiev region). Pilot-cosmonaut of the USSR. Colonel. Hero of the Soviet Union. Member of the CPSU since 1957. Attended a trade school at Belaya Tserkov and a technical school in the Urals, graduating as a building technician. In 1954 he graduated from a military flying school and became a military pilot. Graduated from the Air Force Engineering Academy in Moscow in 1968. On August 12—15, 1962, together with A. G. Nikolayev, Popovich executed a group space flight. The spaceship *Vostok-4* that he piloted made 48 orbits round the Earth in 71 h, covering a distance of about 2,000,000 km.

POPULATION. A community of plants or animals of one species, occupying a definite area of habitation. The probable composition of spaceship's biocomplex populations is monocellular algae, YEASTS, certain species of higher plants, etc.

POROUS ELEMENTS. Porous electrodes and other elements designated for conducting and intensification of various physico-chemical and electrochemical processes in the LSS, energy supply and other systems of spaceship. The extended inner surface of porous elements enables ordinarily slow processes to proceed at much higher rates, while the permeability of porous elements for liquids and gases can be made use of to reduce the limitations associated with the slow rates of reagent diffusion (to the electrodes of electrolyzers, in the reaction zones of absorbents and desorbers, etc.). In system with pass-through porous electrodes, the products of electrolysis, absorption or desorption can be separated comparatively easily, by their suction through the pores, without using special selective membranes and diaphragms. Porous elements make it possible to conduct physico-chemical processes in conditions of weightlessness. However, a reliably functioning system based on the use of porous elements can be achieved only after further studies of capillary equilibrium, mass exchange, and transportation of liquids and gases through porous elements.

Metallic porous elements are manufactured by sintering in an atmosphere of hydrogen: metal powder freely filled into a mold (free sintering); aqueous slimes of metal powders applied to latticed or perforated sheets (slime sintering); metal powder packed between rollers together with or without a pore-forming agent (roller sinter); or metal powder compression molded together with a pore-forming agent.

Free sintering yields a high degree of porosity (from 50 to 90%), but the porous elements obtained are not sufficiently strong and their electrical resistance is high. The use of perforated plates or screens as the central support of the elements increases their durability, strengthens the bond between the particles of the metal powder and decreases the high internal electrical resistance. Slime sintering is used for applying a porous mass on smooth plates. In this case the powder is retained in the form of a suspension and use can be made of a pore-carrier. Roller sintering is used, in the main, for producing the necessary products in large quantities; in this case the dia and speed of rotation of the rollers greatly affect the porosity; when the powder is evenly distributed between the rollers it is possible to obtain products with uniformly distributed pores; the maximum porosity attained is equal to 60%. Compression of metal powder with the addition of a pore-forming agent in special moulds with subsequent sintering in an atmosphere of hydrogen or some other neutral medium is widely used in the production of porous elements intended for special equipment (electrolyzers, ABSORBERS, DESORBERS, FUEL CELLS, etc.).

POSITION PICK-OFF. An instrument that serves for determining the angular deviation of the spacecraft axes from set directions. The operation of position pick-offs used in systems of orientation is based on a great variety of physical principles (see STAR SENSOR, SOLAR SENSOR, VERTICAL-LINE PLOTTER, MAGNETIC SENSOR OF ORIENTATION, ORBIT GYROSCOPE, ION ORIENTATION SENSOR). In most cases, gyros (single position gyros or more complicated devices, e.g., gyrostabilized platforms) serve as position pick-offs in systems of angular stabilization.

POWER CAPACITY OF RADIO COMMUNICATION LINES. Determines the rate of transmission of information along a given line over a given distance, or the distance of possible communication at a given rate of transmission of information. The power capacity of radio communication lines depends upon the radiated power, transmitting antenna gain, area of the receiving antenna, and noise temperature of the receiver. The rate of transmission of information is directly proportional to the power capacity and inversely proportional to the square of the distance.

POWERED DESCENT. A descent to the surface of a planet, at which the spacecraft is decelerated, with respect to the planet, to the landing speed by operating the retro-rocket engine whose thrust is directed opposite to the spacecraft motion. Is practiced for landing spacecraft on celestial bodies having no atmosphere. Aerodynamic braking is preferable for descent in a dense atmosphere.

POWERED-FLIGHT PHASE. The period of space vehicle flight with operating engines. In most cases, the powered flight phase comes to an end when the orbit altitude is attained and the launch vehicle is separated from the

spacecraft. When the location of the launching site does not allow to shoot the spacecraft directly into the chosen orbit, the flight consists of several powered-flight phases alternating with unpowered intervals with shut-down engines.

POWER OF ROCKET ENGINE. The kinetic energy of the mass of gases in the jet stream flowing from the rocket engine in 1 s. It is equal to half the product of the thrust multiplied by the effective exhaust velocity. Known also is the thrust or effective power, i.e., the useful work done by the engine per second of flight, which equals the thrust multiplied by the velocity of flight. It can be larger or smaller than the power of the rocket engine. The total (for all stages of the rocket) maximum effective power of the rocket engines installed on the Soviet launch vehicles used to orbit the *Vostok* manned spaceships equalled 20,000,000 hp, while on the vehicles that launched the *Proton* satellites it amounted to more than 60,000,000 hp.

POWER SUPPLY SYSTEM. A space-borne system serving to supply current to the instruments and equipment of a spacecraft. The sources of current may be: storage, primary or SOLAR BATTERIES, FUEL CELLS, NUCLEAR-ISOTOPE BATTERIES, nuclear power units, etc. The power supply system usually includes a buffer battery charged by a primary source (e.g., a solar battery) during periods of low loads so that by the time the buffer battery is called upon to carry a load heavier than the primary source can handle, it will be sufficiently recharged. Automatic controls incorporated in the power supply system do the necessary switching as the operating conditions change; they also assist in monitoring the system. Low-voltage (e.g., 28 or 12 V) direct current is generally used for spacecraft power supply. An inverter is used to convert dc into ac necessary for certain instruments. The primary source is most usually a solar battery. Prospective power supply systems will probably employ fuel cells, nuclear-isotope batteries, or nuclear power units.

POYNTING-ROBERTSON EFFECT. The effect of light pressure due to the aberration of light that causes the front part (facing the direction of motion) of a particle circling about the Sun to receive a greater amount of solar radiation than the rear part, whereas the solar energy is re-emitted by the particle isotropically (i.e., evenly in all directions). As a result, the particle gradually approaches the Sun along a spiral trajectory, this being equivalent to its movement within a resisting medium. The Poynting-Robertson effect is practically imperceptible in the case of large bodies. But a cosmic dust particle having a density of 1 g/cm^3 and a radius of 0.01 mm that began its motion within the vicinity of a terrestrial orbit will "descend" to the surface of the Sun along a spiral trajectory in the course of 7000 years. Within the vicinity of a terrestrial orbit, the Poynting-Robertson effect is equivalent to the motion through a resisting medium having a density of 10^{-16} g/cm^3 and has to be taken into account in the case of spacecraft for which the surface area-to-mass ratio approaches 1 cm^2/g (e.g., the *Echo* inflated-balloon satellites).

PRE-LAUNCH PREPARATION. A series of operations performed in order to make the space vehicle ready for launch. It begins after the space vehicle has been erected on the launcher and includes: VERTICAL ALIGNMENT

and AZIMUTH ALIGNMENT of the vehicle, pre-launch check-outs, loading the vehicle with propellant and charging it with compressed gases.

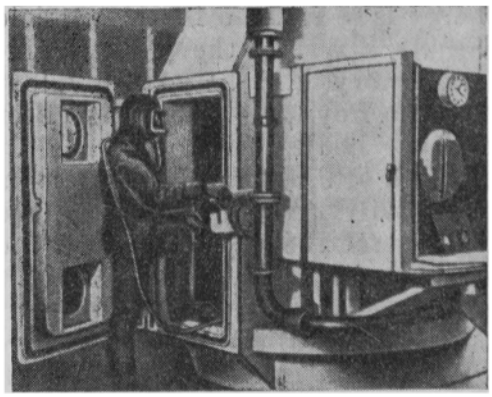
PRELIMINARY DAMPING DUTY. See SUPPRESSION OF SPACECRAFT ANGULAR VELOCITY.

PREMIX CHAMBER. A small chamber in which preliminary mixing and combustion of a liquid propellant takes place and from which the latter is directed into the main combustion chamber for complete burning. Premix chambers were used in spherical (pear-shaped) combustion chambers of liquid-propellant engines.

PRESERVATION OF WASTES. Treatment of liquid and solid biological wastes on board a spaceship by chemical preparations (preservants) to prevent biochemical decomposition during storage. May be substituted by physico-chemical WATER REGENERATION. Numerous combinations of chemicals, e.g., hydrogen peroxide, chromium trioxide, chlorine, or heavy metallic ions, may be used.

PRESERVATIVES. Micro-organism-killing antiseptics. In space flight these substances are practically used for preservation of food products and drinking water on board the spaceship, and for disinfection of urine and feces. Food preservatives include: sulfur dioxide (SO_2) and its aqueous solutions containing 0.15—0.30% SO_2; benzoic acid (C_6H_5COOH) and its sodium salt (C_6H_5COONa) in concentrations of 0.07—10%; sodium chloride; sugar in high concentrations; and antibiotics. Drinking water is preserved by using silver or silver compounds (electrolytic silver in concentrations of 0.1, 0.2, and 0.4 mg/l; silver nitrate in concentrations of 1.5 and 3 mg/l; the preparation *Kumazin* in concentrations of 5.0 and 100 mg/l); ionic silver in a concentration of 0.125 mg/l is the most effective (see WATER STORAGE).

PRESSURE ACCUMULATOR. An element of the rocket power-plant; a vessel which either is filled with a high-pressure gas (air, nitrogen, or helium-type pressure accumulators) or generates the high-pressure gas by burning powder (powder-type pressure accumulators) or liquid fuel (liquid-type pressure accumulators).



Pressure chamber.

PRESSURE CHAMBER. An air-tight chamber for artificial variation of barometric pressure. The pressure chambers are classified as low-pressure (or vacuum) and high-pressure (or compression) chambers, or as stationary and portable ones. A pressure chamber which also allows the temperature to be changed is called a thermal environment simulation chamber. A low-pressure chamber is used in space medicine for studying the effects of high-altitude factors (hypoxia, air rarefaction, atmospheric pressure differential, etc.) and of changed gas environment upon human and animal organisms, as well as for high-altitude environmental

tests and training, for testing high-altitude outfit and equipment, etc. Pressure chambers which simulate the environment at very high altitudes and outer space are called space simulation chambers. They are used for ground tests of spacecraft, their compartments and components.

Pressure in combustion chamber

The capacity of a pressure chamber ranges from several hundreds of l to tens of m^3. As a rule, a pressure chamber is made of two separable parts to allow an object under test to be placed into it. The pressure inside vacuum chambers may range from ambient to 10^{-9} mm Hg. Vacuum to the pressure of 10^{-3} mm Hg is produced by mechanical vacuum pumps; to the pressure of 10^{-5} mm Hg, by diffusion pumps; to the pressure of 10^{-7} mm Hg, by nitrogen entrainment traps, i.e., flasks immersed in liquid nitrogen so that air is condensed in the flasks; and to the pressure below 10^{-7} mm Hg, by employing a titanium spraying technique (in small-capacity chambers) or by using screens cooled down by liquid nitrogen of helium (for large-capacity chambers).

PRESSURE CONTROL in spaceship cabin. Automatic maintenance of the total air pressure in the sealed cabin within pre-set limits. Pressure control is one of the most important functions of the AIR CONDITIONING system. In *Mercury*, *Gemini*, and *Apollo* spaceships pressure control is effected by changing the rate of oxygen supply to the cabin through an oxygen feed device, whereas in the *Vostok* spaceship the pressure is maintained by controlling the oxygen regeneration process. To prevent an excessive pressure rise in the cabin, as well as to balance pressure differences in the cabin and the atmosphere after landing, a special pressure control device is provided.

PRESSURE FEEDING OF PROPELLANT. Feeding of propellant by displacing it from the tanks by means of a compressed gas. Used in low-thrust liquid-propellant engines or when there is little propellant in the tanks. The simples type is the bottle feeding with the aid of a compressed gas (air, nitrogen, or helium) stored in bottles (gas pressure accumulator). The bottle feeding is also frequently used in hold-down tests of rocket engines. Sometimes, gas of the required pressure is obtained from the gas generator burning a solid propellant (powder pressure accumulator) or a liquid propellant (liquid pressure accumulator). See also PROPELLANT LOADING.

PRESSURE IN COMBUSTION (DECOMPOSITION) CHAMBER of a rocket engine. A most important parameter. An increase in pressure in the thrust chamber within certain limits leads to an increase in SPECIFIC IMPULSE (especially if ambient pressure differs from zero) and to a decrease in the dimensions of the rocket engine. This, however, causes an increased pressure in the propellant-feed lines and necessitates the use of more sophisticated turbopumps in the case of liquid-propellant engines with the pump feed; internal pressure and weight increase in the propellant tanks of liquid-propellant engines with the pressure-feed system; it increases the weight of the thrust chamber, intensifies specific heat flows through the walls of the combustion chamber and the nozzle, etc. In view of the advantages resulting from high pressures in the combustion chamber of a rocket engine with a pump feed, this parameter tends to increase. In modern liquid-propellant engines, pressure at the outlet of turbopump rises as high as hundreds of at and in the combustion chamber it amounts to tens and hundreds of at.

PRESSURE SHOCK. The sudden drop in the velocity and jump in density, pressure, and temperature of a gas stream travelling at a supersonic velocity. It is experienced when a supersonic gas stream is decelerated, and may arise in a gas flowing relative to an airframe, in a supersonic gas flow through a nozzle, in a jet stream, at the intake of an air-breathing jet engine, etc. The processes in the pressure shock are irreversible (involve loss of stagnation pressure). A pressure shock in the nozzle of a rocket engine resulting from over-expansion (see NOZZLE EXPANSION RATIO) lowers the losses of thrust and specific impulse conditioned by the over-expansion because the shock increases the pressure on the nozzle inner walls as compared with flow without shock.

PRESSURE SPECIFIC IMPULSE. The product of chamber pressure (to be more precise, STAGNATION PRESSURE in the nozzle throat) multiplied by the nozzle throat area related to the flow rate of the combustion products (working fluid) through the throat. The pressure specific impulse is usually used to assess the completeness of propellant combustion (see COMPLETENESS-OF-PRESSURE COEFFICIENT). There is an actual pressure specific impulse determined experimentally, and a theoretical one (see THERMODYNAMIC ANALYSIS OF ROCKET ENGINE). A similar value used in foreign literature is *characteristic velocity.*

PRESSURE SUIT. The individual equipment (air-tight suit) of a pilot or spaceman which enables him to live and work in rarefied atmosphere or extra-terrestrial space, and maintains the autonomous atmospheric conditions (pressure, temperature, humidity, and composition) within the design limits. There are two types of pressure suits: high-altitude suits and space suits. *High-altitude suits* are to protect the pilot's or spaceman's life if the aircraft or spaceship is decompressed or in case of ejection at high altitudes and/or flight speeds, water recovery or high and low ambient temperatures. Such a suit consists of a soft air-tight suit and rigid air-tight helmet; it may also have air-tight close fitting boots and gloves. According to the system of ventilation and oxygen supply, high-altitude suits are distinguished as ventilated and regenerative suits. Air is fed to the ventilated suit from a compressed air supply (e.g., engine compressor) after passing through flow rate and temperature control units, and is discharged into the cabin or atmosphere. In a regenerative suit the air circulates in a closed circuit; the gaseous mixture passes from the suit to the carbon dioxide and moisture absorbing cartridges from where it goes to the temperature control unit for heating or cooling and then back to the suit. In parachute landings, oxygen is supplied to the spaceman from e parachute oxygen apparatus which automatically begins to operate at the moment of ejection.

A *space suit* is to sustain life and work outside the spaceship in open space or on other planets. The design of a space suit must solve three basic problems; withdrawal of heat, provision of a normal gas environment for respiration and provision of sufficient mobility in joints. Space suits may be of soft or rigid design; as distinct from the high-altitude suit it must have an outer covering with optimal coefficients of heat emission and absorption to protect the spaceman from sharp temperature differentials and ionizing radiation. The double-wall air-tight cover provides reliable sealing. The

viewing window of the pressurized helmet should offer a sufficiently broad field of vision and have a system for protecting the spaceman's eyes against direct sunrays. The ventilation of the suit and oxygen supply are from either a backpack or an on-board breathing apparatus connected with the suit by hoses. In soft-type space suits, the pressure of pure oxygen is maintained within 0.35 to 0.21 kg/cm^2, in rigid-type suits the Earth's atmospheric pressure may be maintained, and ordinary air used for ventilation. Certain elements of the LSS may be connected to the cover structure to purify the gas mixture of toxic substances, remove excess carbon dioxide and moisture, provide additional cooling, etc. A space suit must be fitted with means for movement and orientation, and with a biotelemetry system for measuring principal physiological data and medical monitoring.

PRESSURE TEST. Checking of tanks, pipes, joints, etc. for tightness. The test is performed by filling the tank with compressed gas and observing the drop in pressure, which occurs if there are leaky points; these points can be traced, e.g., by applying a soap solution to the seams, or, which is more accurate, by means of indicators (leak detectors).

PRESSURE-TESTING GUN. A device for pressure-testing, i.e., for checking the propellant-loading and other piping joints for tightness, by building up a required pressure in the pressure-testing chamber located between the sealing gaskets of the joint. It consists of a compressed-air bottle, a gas-pressure reducer, a gun with a needle valve and a pressure gauge for measuring the pressure in the chamber. The end of the gun barrel is provided with a rubber ring which seals the connection between the nozzle and the pipe delivering compressed air to the pressure-testing chamber.

PRESSURE-WARNING UNIT (pressure relay). A transducer that operates at a specific value of pressure. This unit is included in the automatic control circuits of the rocket, the rocket engine and the ground support equipment (namely, in the propellant-loading remote-control system and operation interlock system). The pressure-warning unit is, essentially, a diaphragm-type pressure relay having two-position contact elements that close the "YES-NO" circuit. Several other types of pressure-warning units are known.

PRESSURIZATION OF PROPELLANT TANKS. The introduction into the ullage above the level of propellant in the tank, of a gaseous (usually heated) working fluid at increased pressure. This creates a pressure head of propellant at the pump inlet required to combat cavitation and to ensure the normal operation of propellant pumps and to compensate for longitudinal compressing forces conditioned by rational axial load in the thin-walled shell of integral propellant tanks. Pressurization is achieved either by gaseous products obtained from the main propellant components (in pressurization gas generators, mixers, or heat exchangers-evaporators), or by nitrogen, helium, etc., frequently heated by gas generator gases in a heat exchanger. A powder pressure accumulator is sometimes used for the pressurization. Pressurization is also necessary to prevent thin-walled tanks from collapsing under atmospheric pressure because of propellant consumption.

PRESSURIZATION OF VESSEL. Subjecting a vessel to a pressure higher than the ambient atmospheric pressure by filling it with compressed gas whose pressure is reduced to a certain level. This ensures a static head at the

pumping plant inlet for cavitation-free operation of pumps. Pressurization is also used for pressure feeding the propellant into rockets.

Pressurized compartment

PRESSURIZED COMPARTMENT. Sealed chamber of a spacecraft in which air or some other gas is maintained at a definite pressure. Such a chamber is mandatory in manned spaceships and in this case it is called a pressurized cabin or capsule. On unmanned spacecraft, the pressurized compartment is used to provide favourable operating conditions for space-borne hardware (improved temperature conditions, etc.). It is usually filled with a neutral gas, e.g., nitrogen. To ensure full gas-tightness, the pressurized compartment, usually consisting of several parts, is joined together by means of sealed and bolted bulkheads or frames (using vacuum rubber gaskets). Spacemen exit from a pressurized cabin into free space through an air lock or the cabin may be temporarily depressurized if the spacemen wear life-support suits. Since the compartment may be depressurized by puncture due to the impact of a meteorite, spacecraft intended for prolonged flights lasting several years must have a METEORIC PENETRATION PROTECTION.

PREVENTION OF HARMFUL SPACE EXPERIMENTS (by space law). A complex of international laws precluding any actions in outer space which may impair the exploration and use of outer space for peaceful purposes or may adversely affect the interests of the entire humanity. In the 1967 AGREEMENT this matter is treated in Article IX. It is known that various spacecraft and other objects are circling the Earth. Most of them have completed their missions and do not present any scientific value. To prevent the contamination of outer space by such "dead" objects it is desirable that the different nations agree to reduce to a minimum the number of space object which, although they have lost their scientific and practical value, continue to more around the Earth. Such a reduction could be achieved by an agreement to remove "dead" objects from outer space. The same refers to the stopping of radio transmissions from space objects upon completion of their assignment.

The cause of prevention of radioactive contamination of outer space was greatly promoted by the conclusion of the Moscow Agreement banning nuclear tests in the three mediums and the agreement between the USSR and the USA as to forbidding the orbiting of nuclear weapons or other means of mass annihilation, which was confirmed by the General Assembly Resolution 1884 (XVIII). Provided that different nations strictly observe the obligations following from these international documents, the danger of contamination of outer space by radioactive products will be considerably reduced. It is, however, necessary to take further measures for the investigation and prevention of such contamination in connection with the prospects for the utilization of nuclear rocket engines in spacecraft as well as nuclear power plants.

PROBLEM OF *n* BODIES. The problem of the motion of n bodies (where n is a positive integer) under the action of mutual attraction according to Newton's law of universal gravitation. The bodies in this case are regarded as material particles, which is absolutely true only for bodies of spherical structure, and is approximately true when the mutual distances between the bodies are very great in comparison with their dimensions. Such a pro-

blem is encountered, for example, when studying the motion of planets in the solar system. Up till now attempts to obtain an exact solution of this problem have not met with success. When investigating the planetary motions, the solution of the problem is simplified by the fact that the mass of each planet is considerably smaller than that of the central body, the Sun. Therefore as a first approximation, the motion of the planet under the influence of the attraction of the Sun alone is considered; thus, the problem is reduced to the PROBLEM OF TWO BODIES, that can be solved exactly. Subsequently account is taken off the effect of the other planets. In this manner a solution sufficiently accurate for practical purposes can be attained.

PROBLEM OF THREE BODIES. The problem of the motion of 3 bodies mutually attracted according to Newton's law of universal gravitation. The bodies concerned are regarded as material particles, which is absolutely true only for bodies of spherical structure, and approximately so when the distances between the bodies are very great in comparison with their dimensions. Most often it is necessary to determine the motion of 2 of the bodies relative to the 3rd one. Sometimes the motion of all 3 bodies relative to their common centre of mass is considered. The problem of 3 bodies is encountered, for example, when studying the motion of the Moon under the effect of the attraction of the Earth and the Sun, when studying the motion of stars in three-star systems, etc. Up to now no exact solution of the problem of 3 bodies has been found suitable for calculating the coordinates of the moving bodies or for describing the motion qualitatively. However, in celestial mechanics several approximate methods have been worked out that make it possible, in many cases, to find solutions of this problem that are sufficiently accurate for practical purposes.

PROBLEM OF TWO BODIES. The problem of the motion of 2 bodies mutually attracted according to Newton's law of universal gravitation. The bodies concerned are regarded as material particles, which is absolutely true only for bodies of spherical structure and is approximately true when the distance between the bodies is very great in comparison with their dimensions. Most often it is the motion of one of the bodies relative to the other that is considered. This is practically the only problem of celestial mechanics that can be solved with high exactness to the end. The motion in this problem occurs in conic sections (in circle, ELLIPSE, PARABOLA, HYPERBOLA, straight line) according to Kepler's laws. The problem describes the so-called UNDISTURBED MOTION which is assumed as the first approximation when investigating the actual motion of celestial bodies.

PROFILING OF ROCKET NOZZLE. Shaping the inner surface of a rocket engine's jet nozzle so as to ensure its optimum characteristics. The best possible is the OPTIMUM-CONTOUR NOZZLE. Simplified methods are often used of profiling rocket nozzles to the shape of a parabolic or circular arc, etc. Sometimes nozzles are made conical at a divergence half angle of about 15°. However, simplifications in the methods of profiling or manufacturing of nozzles lead to losses in SPECIFIC IMPULSE and to weight and size penalty.

PROGRAMMED ROTATION. A pre-computed angular change in the ORIENTATION of spacecraft. May be discrete, if only the initial and final angular

attitudes of the spacecraft are pre-set (and, sometimes, the time of transition from the one position to the other), or continuous, if the angular attitude must comply with the assigned program at any moment of time. Programmed rotation is used for performing complicated MANOEUVRES of the spacecraft and for conducting certain scientific studies (e.g., for extending the span of the Earth cloud cover being photographed).

PROMINENCE. See SUN.

PROPELLANT. A substance or combination of substances which constitute the source of energy and working fluid for rocket engines. CHEMICAL PROPELLANTS are used in liquid-propellant, solid-propellant, hybrid-propellant, and other rocket engines; nuclear rocket propellants are intended for NUCLEAR ROCKET ENGINES, mainly for providing energy for an extraneous working fluid.

The history of rocket engine development consists, to a large extent, in the search for effective and handleable propellants, on which the characteristics of the rocket engine principally depend. All existing rocket engines work on chemical propellants; the use of nuclear rocket propellants is only in the stage of development.

The requirements set forth for rocket propellants are numerous and often contradictory. They must provide a sufficient specific impulse (to energetically warrant the use of the propellant), the highest possible density, stability, safety, compatablity with structural materials; adequate sources of raw materials, etc.

PROPELLANT COMPARTMENT. A rocket or rocket stage compartment serving to contain the propellant (fuel and oxidizer) tanks. In a compartment with integral tanks, the tank walls serve as the skin of the rocket and as a structural member bearing longitudinal and bending loads as may act upon the rocket structure. Integral tanks are joined to each other and to other rocket compartments, such as rear section or nose cone, by means of skirts terminating in attachment ring frames. These skirts usually house part of the equipment and fittings. If suspension tanks are used, they are fixed with the respective accessories to the outer airframe structure, i.e., the shell with longitudinal and transverse stress-carrying elements serving to take the external loads acting on the propellant compartment. The outer structure of the propellant compartment is built with end frames for joining it to other compartments.

PROPELLANT CONSUMPTION. The quantity of propellant burnt by the rocket engine per second (propellant flow rate) or throughout the flight (total propellant consumption). The propellant flow rate in case of high-power (high-thrust) rocket engine may be as high as several t/s, while the total propellant consumption in case of flights of space launch vehicles reaches hundreds and thousands of tons.

PROPELLANT DENSITY. For propellants consisting of several separate components, this is a calculated value equal to the ratio of the total mass of the components to their volume at a given value of the EXCESS-OF-OXIDIZING-ELEMENTS COEFFICIENT, or EXCESS-OF-OXIDIZER COEFFICIENT, or MIXTURE RATIO. The density of the propellant is an important parameter in that it determines the size and weight of the propellant

tanks in the rocket and materially influences the EFFECTIVENESS OF THE PROPELLANT, particularly in the lower stages of the rocket.

PROPELLANT DRAINAGE. Drainage of the propellant components from the launch vehicle tanks in the event of a cancelled or abortive launch. The drainage may be brought about by gravity flow due to the hydrostatic pressure of the liquid head, or by establishing a slight over-pressure in the launch vehicle tanks when the servicing tanks are on a level with the launch vehicle. In the latter case, the compressed air is supplied to the launch vehicle tanks from the drainage pneumatic panel via the tank drain safety valves. Drainage can also be performed with the use of a jet pump. In case of gravity or jet pump drainage, it is necessary to open the drain safety valves of the launch vehicle tanks in order to avoid the establishment of a vacuum and, consequently, collapsing of the tanks, caused by external pressure.

PROPELLANT FLOW RATE. See PROPELLANT CONSUMPTION.

PROPELLANT LOADING. The filling of the space vehicle's tanks with liquid propellant components and the charging of rocket-borne pneumatic bottles with compressed gases. The propellant may be pump-fed or pressure-fed to the tanks. Pump-fed systems comprise centrifugal pumps capable of flow rates of several tens of m^3/min of propellant. Pressure-fed systems set up an excess pressure in the ullage of the storage reservoir, this determining the propellant flow rate. To produce the excess pressure, compressed gas at a certain pressure is supplied from the receiver room via a pressure reducing valve. Diagrams of propellant-loading systems are shown in the figures on p. 316.

PROPELLANT-LOADING CONSOLE. Relay and indicating units mounted on instrument racks and connected with a special console which permits the operator to control the processes of loading the launch vehicle with the propellant and charging it with compressed gases and to check the system's response to respective commands. Some panels of the propellant-loading console carry switches for manual control of the hydraulic fittings of the propellant-loading system, as well as push-buttons for start and emergency stop of the control circuit. Other panels hold annunciators indicating the readiness of the propellant-loading system and showing the conditions under which the loading proceeds. A separate panel contains a diagram of pneudraulic circuit of the propellant-loading system. In addition, the panels carry recording instruments of the system for propellant-loading measurement and control. The propellant-loading console is a component of the propellant-loading remote-control system.

PROPELLANT-LOADING FITTINGS. Various devices used in a launch complex and designed for flow control of rocket propellants and for propellant cut-off while fuelling or de-fuelling a launch vehicle. These are: all kinds of valves built into the hydraulic mains of the propellant loading system, connecting elements (flanged joints, pipe connections, nipples, etc.), and instrumentation (pressure gauges, level gauges, etc.). The valves are usually two-position (open—closed) elements for absolute separation of two sections of a pipeline. They are automatically, remotely, or manually controlled and may be electrically, electro-mechanically, or pneumatically actuated. Valves are classified into stop valves (or cut-off valves), vent val-

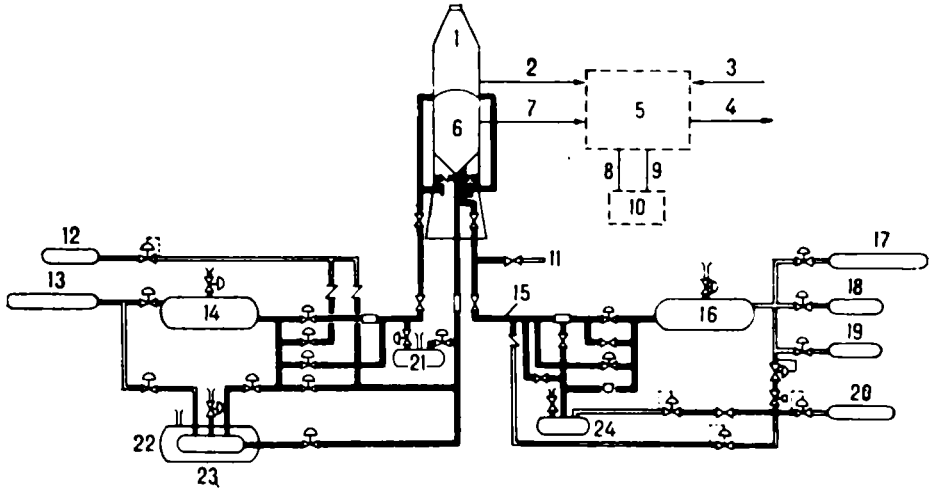


Diagram of propellant-loading system.

1—drain valve of liquid oxygen tank; *2*—signal from level gauge of liquid oxygen; *3*—control commands from propellant-loading console; *4*—feedback from metering system to propellant-loading console; *5*—control relay blocks; *6*—fuel tank; *7*—signals from fuel level gauge; *8*—commands; *9*—command monitoring; *10*—launch control console; *11*—pneumatic line for supply of gaseous nitrogen used to blow fuel away from fuel-loading lines after filling rocket tank; *12*—battery of cylinders for blowing oxygen-loading lines with gaseous nitrogen; *13*—battery of cylinders for pressure feeding of liquid oxygen from supply tank to rocket tank; *14*—liquid oxygen supply tank; *15*—liquid detectors; *16*—fuel supply tank; *17*, *18*, *19*—battery of cylinders for pressure feeding fuel to rocket tank; *20*—cylinder with gaseous nitrogen for fuel displacement from drainage tank; *21*—liquid oxygen drainage tank used for draining oxidizer from loading lines; *22*—vessel for oxygen supercooling; *23*—replenishment system for liquid oxygen; *24*—tank for draining fuel from fuel-loading lines after filling rocket tank.

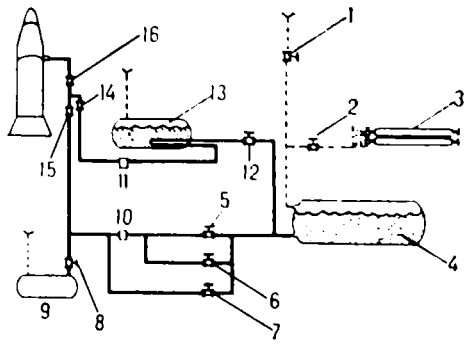
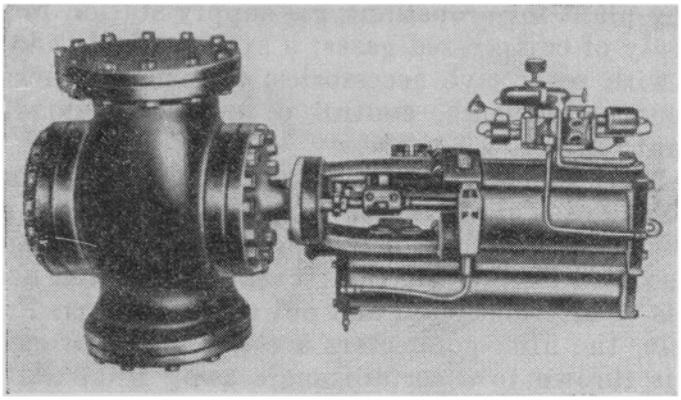


Diagram of loading cryogenic propellants into rocket.

1—drain valve of liquid oxygen supply tank; *2*—control valve for supply tank pressurization; *3*—battery of cylinders containing gaseous nitrogen; *4*—liquid oxygen supply tank; *5*—large flow rate valve; *6*—small flow rate valve; *7*—valve for draining liquid oxygen from rocket tank into supply tank; *8*—drain valve; *9*—tank for draining liquid oxygen from loading lines after filling liquid oxygen into rocket; *10*—liquid oxygen filter; *11*—filter for supercooled oxygen; *12*—valve for controlling oxygen flow rate to supercooler; *13*—vessel filled with liquid nitrogen, containing heat-exchange coil with liquid oxygen (after leaving the vessel, the oxygen has a temperature 6° to 10°K below its boiling point); *14*—non-return valve of supercooled oxygen line; *15*—filler connector; *16*—fuelling valve of rocket tank.

ves, safety valves, drain valves, and non-return valves. The stop valves serve for cutting off propellant flow through a pipeline; the vent (bleeder) valves are used to release liquid propellant vapour or gas from certain pipeline sections, propellant terminals, and propellant tanks of a launch vehicle. Through vent valves, propellant vapour and gases, especially toxic or explosive ones, are released into the atmosphere or directed to special reservoirs



Remote-controlled cut-off valve for use in propellant loading systems

(see PROPELLANT LOADING, PRESSURIZATION OF PROPELLANT TANKS). A safety valve automatically opens as pressure rises above a predetermined limit; such valves are mounted in containers or sections of hydraulic and compressed air mains susceptible to the effect of internal pressure. The drain valves serve for draining propellants from the propellant loading pipeline and from propellant tanks of a launch vehicle. A non-return valve automatically passes a flow of liquid or gas in one direction only; it prevents the propellant from being returned from the launch vehicle tanks to the propellant terminals in the event of an emergency stop of a pump plant or failure of cut-off valves. In hand-operated valves an isolating element is used to control the degree of shut-down of a pipeline cross section. Gate valves are intended to fully or partially shut off a pipeline cross-section with an isolating element that moves at right angle to the pipeline axis; mounted, as a rule, in large-diameter pipelines, they are hand actuated or remotely controlled. The hand-operated and gate valves are used for auxiliary process operations in the course of a launch vehicle fuelling, such as the loading of mains with propellant, pressurization of propellant containers, etc.

PROPELLANT-LOADING REMOTE CONTROL SYSTEM. A space centre system for sequential control of process operations related to loading the launch vehicle with propellants. The system can be operated either manually or automatically. In the former case each successive operation is performed by the operator from the propellant-loading control panel (by switching the corresponding electric control circuit) while in the latter case all the operations follow one another automatically. The functioning of the propellant-loading remote control system is indicated on the pneudraulic display panel by light

signals and by signal lamp annunciators located on the propellant-loading control console. The propellant-loading remote control system comprises a control console accommodating the units controlling individual units and systems, a relay cabinet, junction boxes and cable lines.

PROPELLANT-LOADING STATION. Plants and systems used for supplying the space vehicle with liquid propellants and compressed gases. The equipment of a propellant-loading station includes: PROPELLANT TERMINAL reservoirs; a pumping plant for propellant; gas supply station for the production, storage and supply of compressed gases; a system of gas and hydraulic pipelines provided with respective accessories; systems of thermostatic control of the propellant components, control of propellant loading and control of process operations.

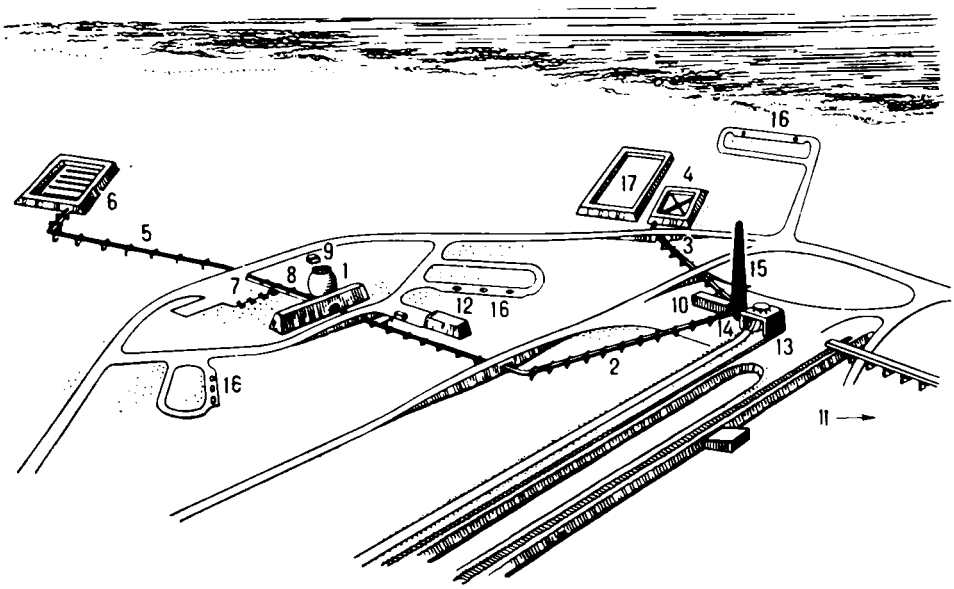
PROPELLANT-LOADING TOWER. An element of the launcher, a tower-like metal structure used for bringing propellant-loading pipelines and filler connectors up to the filler necks of the higher-than-first stages of the launch vehicle. It is also used for fuelling the 1st stage if its filler necks are arranged on the side walls of the stage shell and not on its bottom. Prior to launching the space vehicle, the filler connectors are withdrawn from the filler necks, and the tower is thrown to a certain angle away from the vehicle in order to prevent collision of the latter with the tower during take-off. If the propellant-loading tower is also used for bringing electric cable lines up to the launch vehicle, it is referred to as an umbilical tower.

PROPELLANT OSCILLATION in space vehicle tanks. A phenomenon affecting the stability of a space vehicle, in most cases unfavourably, and complicating the operation of its angular stabilization system. Especially sensitive to these oscillations are launch vehicles where the weight of the liquid propellant may comprise 80—90% of the total initial weight of the rocket. In order to decrease propellant oscillation, auxiliary diaphragms are installed in the tanks.

PROPELLANT SUPPLY TANKS. Reservoirs for storing liquid propellants. They can assume the shape of cylinders or ellipsoids with spherical or elliptical end-plates, as well as the spherical shape, etc.; the tanks may be portable on a self-propelled or towed chassis, or stationary mounted on a foundation either above or below the ground surface. The propellant-supply system also comprises auxiliary containers to receive propellants drained from the hydraulic pipes upon completion of fuelling. For loading the propellant and checking the loading procedure, the tanks are equipped with various systems and instruments. These include the "breathing" system of the tank maintaining a certain pressure inside regardless of temperature variations of the propellants; safety valves for releasing surplus pressure; level indicators and filling signal units. Some tanks are provided with remote thermometers showing the mean temperature of propellant, fittings for pressurizing the tanks with compressed gas and for the thermostatic control of the propellant. The tanks for cryogenic propellants are heat-insulated to minimize propellant losses in storage and during loading.

PROPELLANT TERMINAL. A surface or underground structure at the launching site, accommodating vessels for storage of rocket propellant. Following systems are provided: gas control and ventilation, propellant temperature

control, thermostatic control, propellant vapour discharge and neutralization, fire-fighting, propellant loading into the vssels ferom mobile tanks, and pressurization by compressed gas.

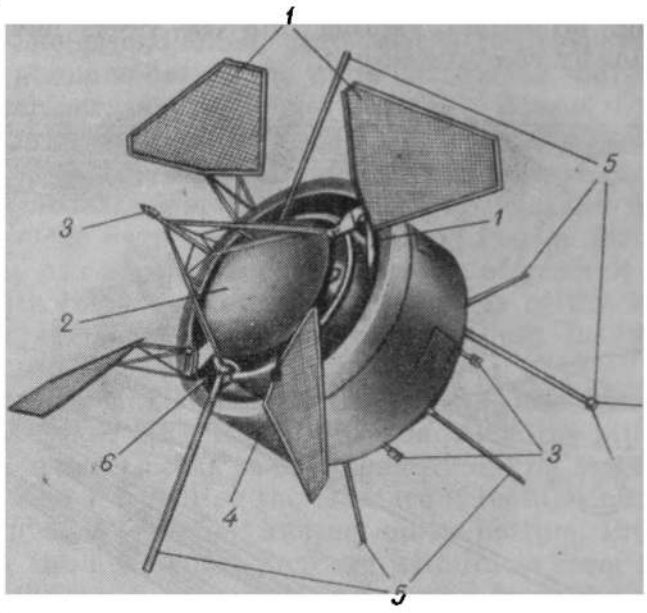


Arrangement of structures and units of propellant-loading equipment on launching site

1—spherical vessel for storing liquid hydrogen; *2*—pipeline for loading liquid hydrogen into rocket; *3*—drain pipeline for removing gaseous hydrogen from rocket tanks; *4*—site for burning gaseous hydrogen removed from rocket tanks; *5*—drain pipeline in hydrogen storage area; *6*—site for burning gaseous hydrogen; *7*—filler manifold for charging the vessel with liquid hydrogen; *8*—coil of pumping system; *9*—facilities for electric power sources; *10*—propellant-loading control center; *11*—launch control center; *12*—fuel storage area; *13*—zone for service tower; *14*—launcher; *15*—service tower; *16*—location of cinema and photographic equipment; *17*—evaporation site.

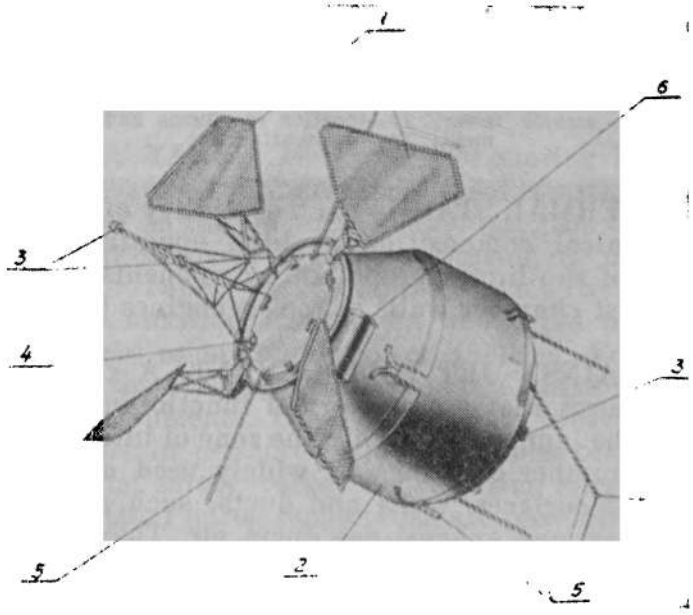
PROPELLANT THERMAL STABILITY. The ability of a propellant to retain a permanent chemical composition at high operating temperatures. The thermal stability of the liquid propellant components used for regenerative cooling of the thrust chamber walls of rocket engines (heated to 200—250°C) must be high.

PROTECTION AGAINST JET IMPINGEMENT. A combination of design and operating features that ensure normal functioning of the launcher and other elements of the launch site within the zone of intensive jet impingement during a specific number of firings. A widely used method is arrangement of shaped deflecting surfaces, walls and ducts, such as GAS BAFFLES, FLAME CHUTES, FLAME DEFLECTORS, exhaust-gas ducts, etc. They prevent the jet from damaging the equipment and launch vehicle. Many launcher elements are protected against direct jet impingement by special casings, protective walls, hoods, covers, etc. The required durability of the flame deflecting surfaces is provided by use of appropriate materials and wall thickness. In addition, protection is provided by special coatings (heat-proof, plastic, ceramic or rubber covers, layers of spray-applied refractory materials).



Satellite of *Proton-1, 2, 3* series

1—solar cell panels; *2*—sealed body; *3*—sensors of satellite axes attitude indicating system; *4*—outer skin; *5*—antennas; *6*—chemical batteries.



Proton-4 satellite.

1—panels of solar batteries; *2*—sealed body; *3*—transducers signalling spatial attitude of the satellite's axes; *4*—dampening system actuators; *5*—antennas; *6*—containers housing buffer chemical batteries.

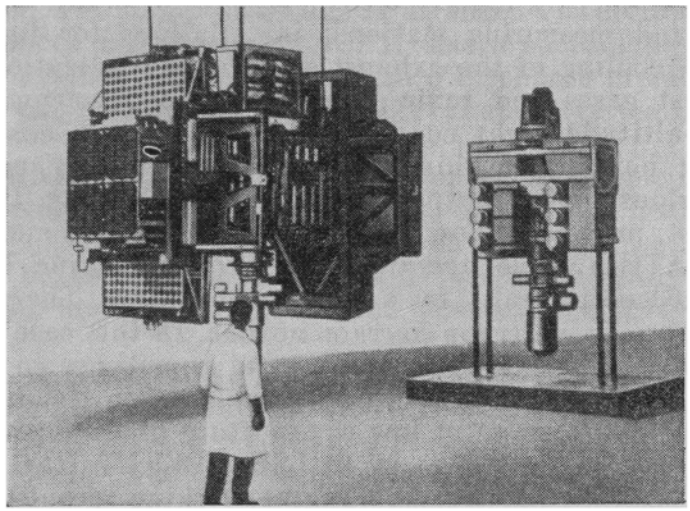
PROTON. The name of series of heavy Soviet scientific Earth satellites launched to investigate cosmic rays and the interaction between high-energy particles and matter.

Proton

launch vehicle

Proton-1, *Proton-2* and *Proton-3* were launched on July 16 and November 2, 1965, and July 6, 1966, respectively. Each of these satellites plus the equipment housed in the upper stage of the launch vehicle, weighed 12.2 t. The instruments package weighed 3.5 t. Their orbits had a perigee of 190 km and an apogee of ~630 km. Scientific package included an ionization calorimeter for the study of particles with energies of up to 10^{13} eV.

Proton-4 (see Fig. on p. 320), launched on November 16, 1968, carried a new and unique experiment package which permitted the range of energies studied to be extended to 10^{15} eV. The weight of *Proton-4* (less upper stage of launch vehicle) was 17 t; the scientific package weighed 12.5 t. Its orbit had



Scientific packages of *Proton-1*, *-2*, *-3* (right) and *Proton-4*.

a perigee of 255 km and an apogee of 495 km. The experiments carried out by the *Proton* series included study of the energy spectrum and chemical composition of primary cosmic particles, and the intensity and energy spectrum of gamma rays and electrons of galactic origin. By means of these satellites new and unique data have been obtained.

PROTON LAUNCH VEHICLE. The powerful multi-stage multiple-engine launch vehicle used in 1965—1968 to launch 4 *Proton* scientific satellites, each weighing up to 17 t. The payload capacity of this vehicle is much greater than that of any of its predecessors. The maximum total effective power developed by its engines exceeds 60,000,000 h.p. or threefold the power of the *Vostok* launch vehicle. The *Proton* vehicle incorporates the latest achievements of space/rocket science and technology and has demonstrated high operating and power characteristics due mainly to the use of new engines

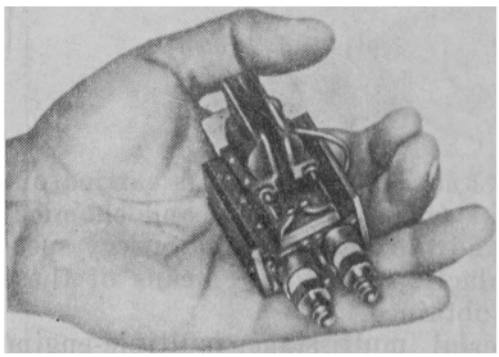
Proving stand

built according to advanced design concepts. High pressure in the engine and complete combustion combined with uniform and balanced exhaust of combustion products from nozzles with a high expansion ratio have gone into the making of a compact engine of high performance. The development of a launch vehicle powered by such engines is a marked achievement of Soviet rocket engineering. Successful launching of the *Proton* vehicles may be considered to be the beginning of a new stage in the study and conquest of outer space and has opened the way for new discoveries in near-Earth and near-solar space by means of massive spacecraft.

PROVING STAND. A complex installation with process equipment, control gear, and measuring instruments, used for hold-down FIRING TESTS of rocket engines. The rig comprises a firing section with carriages equipped with thrust-measuring devices (under the rocket engine); a propellant bay with fuelling and defuelling devices, a pressurization and draining system, and supply manifolds; automatic electric, pneumatic and hydraulic equipment; control and measuring stations; installations for light absorption, sound damping, cooling of the exhaust system, neutralization of toxic products in exhaust gases and toxic propellant waste; vacuum installations imitating high-altitude flight conditions; THERMOSTATIC CONTROL systems; a blast system; hoisting machinery for assembly and dismantling of the engine and various equipment; facilities for calibrating the systems for measuring thrust, propellant flow rate, etc.; and numerous auxiliary services.

PULSE OPERATION. The operation of a rocket engine in pulses, i.e., when it is ignited periodically for a pre-set short time. The pulse operation is used, for instance, in ATTITUDE CONTROL MOTORS. In this case the pulse time of their operation is measured in tenths and sometimes in hundredths of a second. Such an operation of engines to maintain a steady-state orientation is most efficient because of low expenditure of the working fluid.

PULSE ROCKET ENGINE. A rocket engine working in pulses due to periodical injection of propellant (for a liquid-propellant engine), or periodical heating of the working fluid for its sublimation or heating it (for an electrical rocket engine). It is used for orientation and stabilization of space vehicles.



A liquid-propellant pulse rocket engine of the attitude control system of an Earth satellite firing nitrogen tetroxide and a mixture of hidrazine with unsymmetrical dimethylhydrazine (USA).

PUMP FEED. A system of feeding the propellant or the working fluid from the rocket tanks into the rocket engine by means of pumps. The pumps are subdivided into main and auxiliary ones. Used as main pumps (see ENGINE PUMP) are mainly single-stage or multi-stage CENTRIFUGAL PUMPS or AXI-

CENTRIFUGAL PUMPS (sometimes axial). The main pumps have a high head. Auxiliary pumps see under BOOST PUMP.

PUMPING PLANT. A mobile or stationary pump assembly for fuelling launch vehicles at a space centre. The plant consists of pumps (mostly of the centrifugal type), a system of plenum and suction pipelines with flow control and shut-off fittings, electric drive motors, and a system of plant control. The centrifugal pumps are capable of working with the gate valve closed, which comes in useful in case of an emergency closing of the cut-off valves. The pumps are driven by asynchronous motors with a rated power from a few tens to several hundreds of kW.

PUMP-OUT PLANT. A pumping plant included in the launcher of a space centre and designed for pumping out the water used for setting up a fire-fighting water curtain, as well as for removing rain water that is liable to accumulate at the bottom of gas ducts and channels if the latter are below the ground level. The pump-out plant is arranged at the lowest level of the gas discharge ducts and flame chutes. It has a suction pipeline and filter for drawing off drain water from pits, and a discharge pipeline along which the drain water can be expelled to ground level and diverted from the launching site.

PYROLYTIC GRAPHITE. Oriented graphite, an allotropic form of carbon with a high sublimation temperature (~4000°C) and high heat of sublimation (~5550 kcal/kg), deposited in the process of pyrolysis, i.e., decomposition of methane by heating it above 2000°C. Deposits of pyrolytic graphite on ordinary graphite are used to protect the surfaces of nozzles of rocket engines, etc.

PYROTECHNICAL IGNITION. Initiation of combustion in rocket engines by means of cartridges that burn in the combustion chamber of the gas generator in the course of several seconds and produce a torch of high-temperature gases. Used in solid- and liquid-propellant engines burning a propellant whose components do not ignite spontaneously on contact.

Q

QUASILIQUID PROPELLANT. A solid propellant or its component (oxidizer or fuel) fluidized by gas using the boiling layer method. In contrast to a hybrid propellant, it can be used in rocket engines designed to the liquid-propellant engine scheme.

QUASINEUTRAL PLASMA. See IONOSPHERE.

RADIANT. See METEOR STREAM.

RADIATION ABSORPTION FACTOR. The ratio of the amount of the absorbed heat energy to the energy of luminous flux falling on the given surface. As referred to the solar radiation, it is called the solar absorptance factor. The required value of radiation absorption factor ensuring the heat balance of a spacecraft is obtained by special treatment of its outside surface or by applying respective coatings thereto.

RADIATION BALANCE OF EARTH. The balance of thermal radiations as determined by the ratio between solar radiation absorbed by the "Earth's surface—atmosphere" system and the EARTH RADIATION. The annual average of radiation balance of the Earth equals zero. The principal factors of the variability of radiation balance of the Earth are cloudiness, albedo, and the temperature of the underlying surface. The radiation balance of the Earth has a latitudinal, diurnal and annual variability; near the equator the balance is always positive; in the high latitudes it is nearly always negative. The annual average value of radiation balance of the Earth in the zone 0—10° N.L. is 0.403—0.347 = 0.056 cal/cm^2·min, while in the interval of 80—90° N.L. it is 0.106 — 0.245 = — 0.139 cal/cm^2·min (where the minuend is the absorbed solar radiation and the subtrahend is the Earth radiation).

RADIATION BELT OF EARTH. Zone of radiation trapped by the Earth's magnetic field (see GEOMAGNETIC TRAP). The radiation belt is composed of charged particles with energies far surpassing the energy of the thermal particles of the outer ionosphere and involved in regular limited motion in the geomagnetic field under the action of the Lorentz force. The nature of the movement of particles in the radiation belt is determined by the structure of the magnetic field. Spatial distribution and angular anisotropy of radiation (distribution of intensity by pitch angles, or angles relative to the line of force) depend on the mechanisms of the supply and loss of particles. The division of the belt into the internal and external parts is one of convenience and is due in the main to the special features of the instrumentation used in the first space experiments. At present it is known that the particles of the radiation belt of the Earth—electrons and protons—fill the entire region where the lines of force of the geomagnetic field are closed, starting with several hundreds of km above the Earth's surface to the limit of the magnetosphere.

The distribution of protons has been well studied in the range of energies from 100 keV upwards; at small distances from the Earth (approximately up to 5000 km) the dominant protons have energies of tens of MeV; with increasing distance from the Earth, their spectrum becomes more and more steep. The proton fluxes are maximum at a distance of $\sim$3.5 R_E; drift of these protons (with an energy of $\sim$10 keV) gives rise to circular current. The intensity of protons is subject to variation both in the inner and outer zones of the belt, these variations coinciding in time with MAGNETIC STORMS. The appearance of protons with energies measured in hundreds of keV in the outer regions of the magnetosphere has been recorded during polar substorms. Apart protons, some evidence points to the existence in the radiation belt of the Earth of deutrons, tritons, and α-particles. More detailed data have

been collected on the behaviour of electrons in the radiation belt; both in the inner and outer zones of the belt there are observed great fluxes of electrons with energies of tens and hundreds of keV. The electron spectrum also becomes softer with increasing distance from the Earth. An interesting point is that electrons with energies >780 keV (treshold of neutron β-decay) are also observed in radiation belt. Electron intensity and spectrum variations are particularly great in the outer regions of the magnetosphere. During magnetic disturbances the intensity of the high-energy component (with an energy of the order of hundreds of keV or more) sharply diminishes while the intensity of soft electrons (of the order of tens of keV) increases; after that the flux of high-energy electrons gradually increases and may surpass the original value. The flux of low-energy electrons experiences very rapid and strong variations.

On the basis of experimental data it has been possible to identify a number of processes affecting the electrons of the outer belt: rapid non-adiabatic acceleration and rapid losses (either of the amount of energy or of the quantity of particles), slow losses (apparently due to scattering of particles), radial diffusion and adiabatic acceleration. However, many details of the physical processes and the origin of particles of radiation belt require further study. Apart from the natural radiation belt, an artificial belt exists as well. This belt formed as a result of the American high-altitude thermonuclear blast code-named *Starfish*, in 1962. This belt of electrons with energy of ~1 MeV is situated at the height of 1000—2000 km; its intensity gradually declines with time as a result of scattering and loss of energy by electrons, but to this day it interferes with measurement of natural electrons in this region of space. The average intensities of protons and electrons in the radiation belt of the Earth are given in the following table.

Zone of the belt	Protons		Electrons	
	energy	intensity	energy	intensity
Inner	⩾1 MeV	$3 \cdot 10^6$ cm^{-2}.s^{-1}	⩾40 keV	$3 \cdot 10^8$ cm^{-2}.s^{-1}
	⩾30 MeV	$2 \cdot 10^4$ cm^{-2}.s^{-1}	⩾600 keV	$5 \cdot 10^6$ cm^{-2}.s^{-1}
Outer	⩾100 keV	$2 \cdot 10^8$ cm^{-2}.s^{-1}	⩾40 keV	$2 \cdot 10^7$ cm^{-2}.s^{-1}
			⩾1.6 MeV	$1 \cdot 10^5$ cm^{-2}.s^{-1}

Particles of the radiation belt present serious radiation hazard to manned space flight.

RADIATION COOLING. The cooling of units of a rocket engine and surfaces of a space vehicle by radiating heat from the surface into the environment (see COOLING OF ROCKET ENGINE). The efficiency of radiation cooling depends on the shape and orientation of the radiating surface, the degree of its blackness (especially in the IR range), the parameters of the environment, and the shapes and locations of the surrounding surfaces. Radiation cooling is effective when applied to the high-altitude nozzle of a single-chamber engine if the rocket has but one engine.

RADIATION DOSE. The electromagnetic radiation is measured in roentgens (r). 1 r is a dose in which the total charge of positive and negative ions in 1 cm^3 of air (weighing $1.293 \cdot 10^{-6}$ kg) is $1/(3 \cdot 10^9)$ C. When a spaceship passes through the Earth's radiation belt, it is exposed to a radiation dose of 2—3 r/h.. During powerful solar flares the radiation dose may be several thou. r/h. A dose of 400—600 r is lethal for man, but there are micro-organisms that survive exposure to doses of several hundred thousandr.

RADIATION PROTECTION. Means for protecting the crew against the radiation of space, nuclear reactor, or isotope generator of the spaceship. Radiation protection is normally a layer of some substance absorbing the radiation coming from without. To be valid against space radiation, the protection should be all-direction, i.e., it should surround the spaceman from all sides. To a certain extent radiation protection is provided by the substance of the spaceship airframe and equipment arranged round the crew, such protection containing on the average a few g of substance per 1 cm^2 of surface. With high intensity of cosmic radiation, e.g., during solar flares or in flights within the RADIATION BELT OF EARTH, the intensity of radiation protection must be appreciably greater (tens and hundreds g of substance per cm^2 of surface). In such cases it is rational not to protect the whole spaceship, but only some of its compartments intended for accommodating the crew, i.e., to provide what is known as radiation shelters. Radiation protection of the spaceship nuclear reactor is normally located only between the reactor and vehicle compartments (so-called shadow protection).

RADIATION SYNOPTICS. A method of studying the synoptical situation on the basis of analysis of the field of Earth radiation; from the viewpoint of radiation synoptics most informative is the EARTH RADIATION in water-vapour windows, which permits to characterize the distribution of the cloud cover and thus to assess the specific features of the synoptic situation. Distinctly revealed in the field of this radiation are the vortices of hurricanes and typhoons; using data of its measurement, it is possible to determine the temperature of the underlying surface and cloud height.

RADIATIVE SURFACE. The part of the external surface of spacecraft or a thin-walled shell designed as a separate structural element, whose purpose is to radiate the excess heat evolved in the spacecraft so as to maintain the temperature within required limits. See TEMPERATURE CONTROL SYSTEM.

RADICAL. An atom or group of atoms with free valency, which normally exists only when bound with other atoms in a molecule. Free radicals, which as parts of molecules possess greater energy than in the bound state, can be obtained during combustion, explosion, photolysis, electrical discharge, and other phenomena and can be fixed by rapid cooling. Because radicals are capable of releasing large amounts of potential chemical energy in the rocket engine, they are being studied as prospective rocket propellants (see MONATOMIC PROPELLANT); however, methods of industrial storage of free radicals are yet to be found.

RADIO ASTRONOMY. That branch of astronomy which makes use of radio-telescopes for investigation into the astronomical objects (celestial bodies of the SOLAR SYSTEM, GALAXY and METAGALAXY) by observations of the radio waves that they emit, the latter being in the range of a few mm to 40 m

(see ASTROPHYSICS). Data yielded by radio-astronomic investigations can be interpreted to disclose valuable information including that on: (*a*) the Sun atmosphere the different layers of which emit most effectively the energy on different wave-lengths (which allows its observation as if it were in cross section); (*b*) sunspots, flares or other solar phenomena, which make it possible to forecast the appearance of corpuscular fluxes (including cosmic rays of the solar origin) disturbing the Earth atmosphere and being hazardous to spacecraft; (*c*) brightness temperatures, and other characteristics of the surface layers and atmospheres of planets (e.g., those of Venus); (*d*) radio flares at the moment of optical flashes of some stars of Galaxy, which give some information on the physical conditions in the fields under study; (*e*) Metagalaxy where over 10^4 radio-wave sources are observed, most of which are galaxies with their own properties, e.g., with very intensive radio luminosity; most peculiar are superstars (quasars) of highest radio emission and variability (quite unusual for objects of metagalaxy), which are at a vast distance from the Earth. Radio astronomy finds practical application, the most important of them being that for all-weather navigation (employment of radio sextants oriented on the Sun, the Moon, and other sources of radio waves); passive location (receiving the thermal picture of the Earth's surface); antenna technique (measuring the parameters of large antennas by observation of known cosmic sources of radio emission). Radiolocation astronomy has developed into an independent branch which concentrates on a study of some planets, the Moon, meteors, etc., by applying the methods of radiolocation, especially when optical observation is impossible, e.g., for obtaining more accurate information on the orbits of planets (the dimensions of the Solar system), physical conditions on the surface of planets, the Moon, etc.

RADIO CHANNEL. A frequency band assigned for radio communication of a specified type (telephone, telegraph, TV, etc.). Taking into account the frequency instability of the radio transmitter and receiver, radio channels of a greater width than the frequency spectrum of the transmitted messages are adopted for communication.

RADIO COMMUNICATION. A system of communication established with the view of transmitting any kind of information between 2 or several stationary points or moving objects by means of radio waves. According to the adopted mode of operation, radio communication is classified as: one-way (when one point is used only for transmission, and the other, or others, only for reception), two-way (when each point transmits and receives signals), simplex (two-way radio communication at which each point transmits and receives signals, alternately) and duplex (two-way radio communication with simultaneous transmission and reception at each point). See SPACE COMMUNICATION.

RADIO COMMUNICATION REGULATIONS. A document drawn up by the International Scientific Radio Union, that establishes standard frequency bands and rules for their use for various kinds of radio communication. Frequency bands to be used for space communication were established by the Extraordinary Administrative Conference on Radio Communication in Geneva, 1963. This decision has come into force in 1965 after ratification by the governments of the country-members of the International Scientific

Radio Union. The radio communication regulations also contain recommendations applying to the joint use of frequency bands by different services, levels of radio interference, terminology, etc.

RADIO-INERTIAL NAVIGATION. A system of space navigation making joint use of inertial and radio means of navigation and, consequently, notably free of many of their individual disadvantages. In particular, the employment of radio equipment enables one to avoid accumulation of errors occurring at sole use of inertial means of navigation, whereas the latter allow to obtain information relating to the motion of the spacecraft during MANOEUVRES, TRAJECTORY CORRECTION and other phases of the flight, whose short duration makes radio means of navigation inefficient.

RADIO INTERFERENCE. Random electromagnetic oscillations and disturbances liable to distort the radio signals being received. Ratio interference is classified as internal (RADIO RECEIVER NOISES) and external (affecting the antenna or supply circuits externally), the latter being caused by radio transmitters operating on neighbouring frequencies, by INDUSTRIAL RADIO INTERFERENCE, by COSMIC NOISE, ATMOSPHERIC NOISE, and EARTH NOISE. Radio interference due to the operation of radio transmitters on neighbouring frequencies is reduced by selecting the frequency of the received signals so that it differs greatly from the interfering frequencies, and by the insertion of electric filters into the receiver circuits. Interference of noise is lessened by increasing the power of the received signals and employing special input circuits, adopting appropriate methods of processing of the received signals, narrowing the frequency pass band of the radio receiver, efficient coding of the transmitted messages, and by other suitable means. Suppression of radio interference is of special importance when ground radio communication stations receive very weak signals from spacecraft.

RADIOISOTOPE ROCKET ENGINE. A rocket engine using the decay energy of radio isotopes of chemical elements, usually artificial ones (e.g., polonium-210 or strontium-90) or transuranium ones (e.g., plutonium-238, curium-244). This energy serves to heat the rocket engine's WORKING FLUID, or the products of decay themselves serve as the working fluid forming the efflux. Experimental radioisotope rocket engines develop a very low thrust.

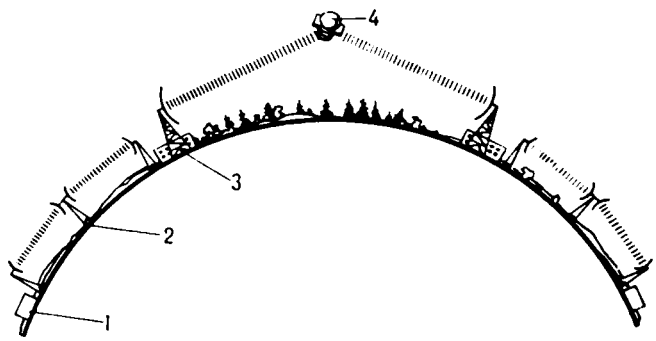
RADIO MONITORING OF ORBIT. Determining the parameters of spacecraft orbit with the aid of ground radio station (see RADIO NAVIGATION). Is resorted to periodically for more accurate measurement of the orbit parameters which are liable to change gradually due to the influence of various disturbances. Such periodic check-ups supply data required for subsequent correction of the orbit.

RADIO NAVIGATION. A spacecraft navigation system in which the position and velocity of the spacecraft are determined by radio facilities including a network of ground transmitter-receiver stations and spacecraft-borne responders or radio beacons. Radio navigation enables to measure the angular positions of sight lines joining the ground stations and the spacecraft, the angular velocity of displacement of these lines, the distance to the spacecraft along the sight lines, and the speed of the spacecraft with respect to

the ground stations. The results of measurements are analyzed on the Earth.

RADIO RECEIVER NOISES. Irregularly varying currents arising in the input circuits of a radio receiver due to the thermal motion of electrons and irregular motion (discreteness) of charges in electronic equipment connected to the input circuits for converting and amplifying the received messages. Receiver noises limit the intelligibility of messages as they make it extremely difficult, and frequently even impossible, to separate them when signal levels are equal to or below the receiver noise level. The quality of reception is improved by making use of low-noise parametric and maser amplifiers and of special methods of processing (integration, correlation, etc.) of the messages received which separate the latter when signal levels are below the level of receiver noises.

RADIO RELAY LINE. A line of radio communication for simultaneous transmission of hundreds or thousands of telephone and telegraph messages or a TV program in the SHF band along a chain of ACTIVE RELAY STATIONS



Schematic diagram of radio relay line.
1—line terminal; *2*—intermediate point; *3*—ground-based station for radio communication with satellite; *4*—repeater satellite.

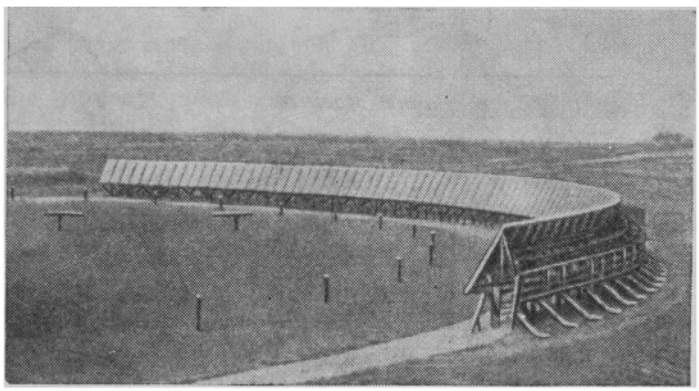
and PASSIVE RELAY STATIONS. The antennas of the relay stations are installed on high towers arranged within sight of each other (spaced 50—70 km apart) at intermediate points of the communication line. Earth satellites may serve as intermediate points of a radio relay line.

RADIO RELAY LINE WITH DELAYED RELAYING. A radio relay system for the transmission of messages from one ground station to others via a NON-STATIONARY SATELLITE carrying radio-electronic equipment provided with a memory unit for storage of messages transmitted from earth. The messages are received, recorded and stored by the memory unit of the satellite in the course of its passage over the first ground station. During subsequent flight over other ground stations of the radio relay system, this process is reversed by command from earth, i.e., the recorded messages are re-transmitted from the satellite to the respective ground station.

RADIO SIGNAL DELAY. A phenomenon due to the finite velocity of propagation of radio waves; the time interval equal to the quotient at division of the distance between the radio transmitter and receiver by the propagation velocity. When radio signals are relayed via an Earth satellite or any

other body in outer space, the distance determining the delay includes the distance from the radio transmitter to the relay station and from the latter to the receiver. The delay involved at passage of the signals through the relay equipment is to be taken into account when dealing with an ACTIVE RELAY STATION. The radio signal delay equals 0.01 s for every 3000 km.

RADIOTELESCOPE. A device for receiving and recording radio waves emitted from astronomical objects. The most widely used are radiotelescopes in the form of parabolic reflectors: 76-m telescope in Jodrell Bank (Britain), 64-m in Parkes (Australia), 22-m in Serpukhov and in the Crimea



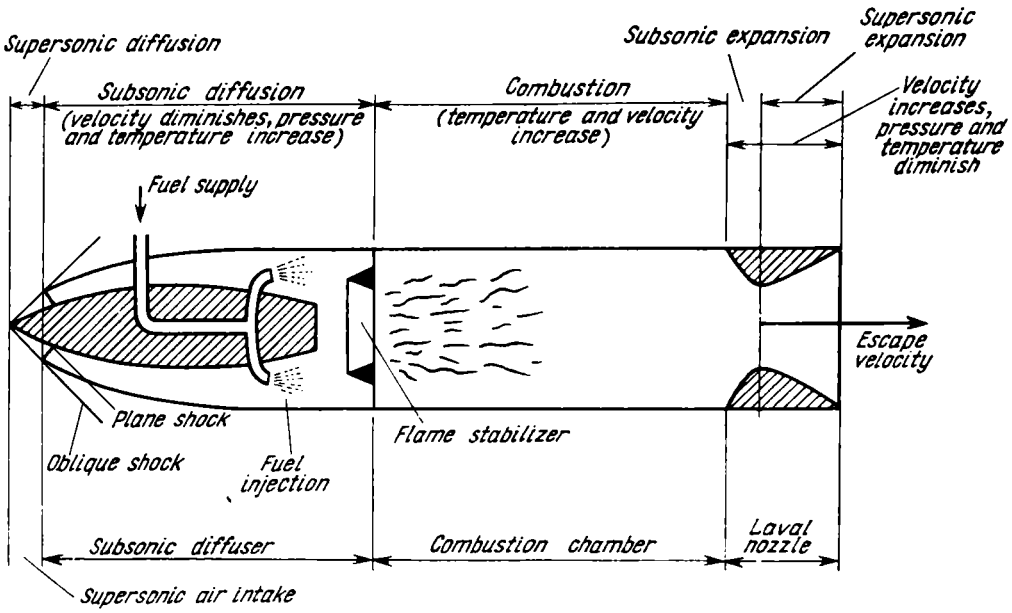
Large radiotelescope at Pulkovo Observatory of USSR Academy of Sciences.

(USSR) and many other. For greater resolving power array antenna grates are used in which a number of mirrors are connected into a united system of great length by means of communication lines, and antennas of aperture synthesis. The synthesizing (joint processing) of observations carried out in different points yields the results which are equal to those from observations with a large antenna. The sensitivity of radiotelescopes in flow is up to 10^{-29} W/m^2·cps with a resolution as fine as a few seconds of arc.

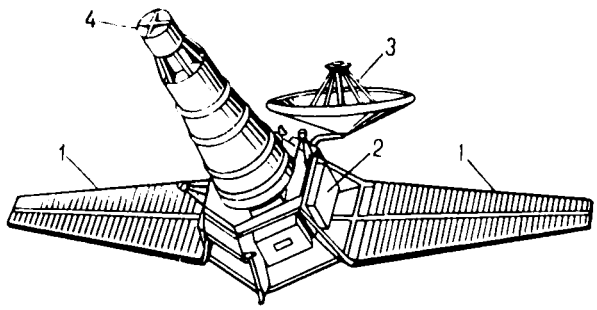
RAMJET ENGINE. An air-breathing engine comprising an air-intake and diffuser combination for decelerating the incoming air stream, a combustion chamber, and a jet nozzle. It can be used at sufficiently high speeds of flight (MACH NUMBER 2—3 and more), but develops no thrust when stationary (M = 0). It is used on guided missiles and can be employed on supersonic aircraft and aerospace planes.

RANGE CONTROL CENTRE. See SPACE CENTRE.

RANGER. The name of a series of US lunar probes, as well as of their development and flight program. The *Ranger* spacecraft are designed to take TV pictures of lunar surface and relay them back to Earth on approach to the Moon. Soft landing is not provided, the vehicle crashes on impact. Each spacecraft weighing up to 365 kg carries 6 TV cameras with different lenses. The 6 initial launchings were unsuccessful, but *Ranger-7*, launched on July 28, 1964, struck the Moon in the region of Mare Nubium. On approach to the Moon (at distances from 1800 km down to 300 m from the lunar surface)



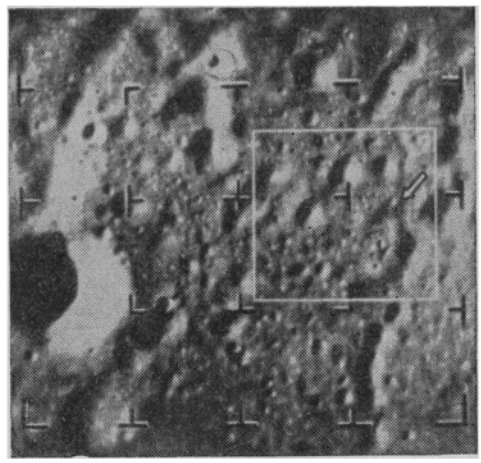
Thor ramjet engine: (*a*) schematic diagram; (*b*) general view.



Ranger spacecraft

1—solar batteries; *2*—container housing space-borne equipment and TV cameras; *3*—high-gain antenna; *4*—semidirectional antenna.

a large number of TV pictures were transmitted which gave the features of the lunar surface. Some of the pictures showed details of 0.5—1 m in size. *Ranger-8* launched on February 17, 1965, and *Ranger-9* launched on March 21, 1965, relayed similar pictures of other lunar areas, *viz.*, in the Crater Alphonsus and Mare Tranquillitatis.



One of the pictures of lunar surface relayed by *Ranger-9* before it struck the Moon. The arrow shows the impact place.

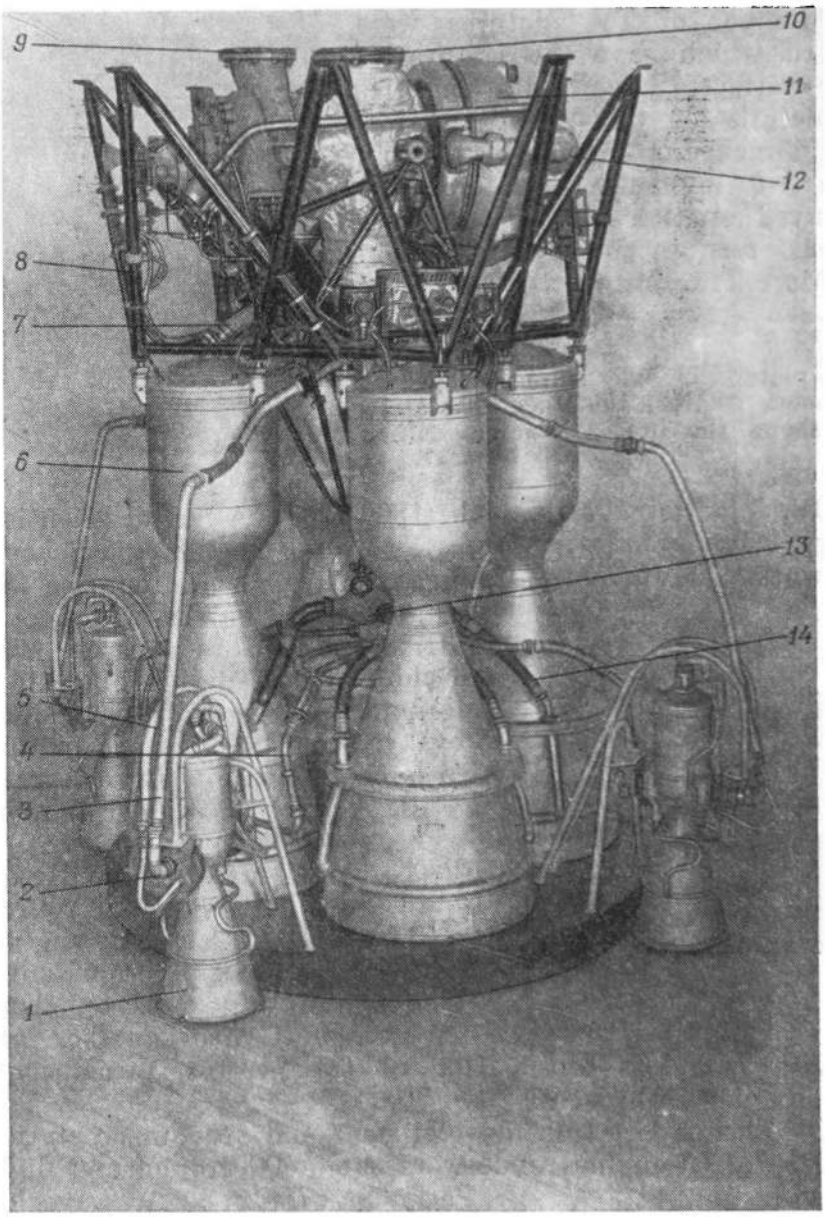
RAZUMOV, Vladimir Vasilyevich (1890-1967). A Soviet scientist in rocket technology. After graduating from the Naval Engineering School in Kronstadt he worked in the ship-building industry. Beginning with 1931 led the Leningrad Group for Study of Reactive Motion. In 1933 in Moscow was appointed chief of the design office to project an all-metal airship drafted by K. E. Tsiolkovsky. From 1956 worked in the Scientific Research Institute of Civil Aviation of the USSR. A crater on the far side of the Moon has been named in his honour.

РД-(1—3) (*RD-1* to *3*). A family of auxiliary liquid-propellant engines for aircraft, developed by GDL—OKB. The engines featured pump feeding of the propellant composed of nitric acid and kerosene, chemical ignition, an unlimited number of repeated firings with complete automation of the process, thrust control, and a maximum sea level thrust of 300—900 kg.

In 1943—1964, apart from development and acceptance static tests, the *РД-1* and *РД-1Х3* engines underwent some 400 ground and flight tests on the following aircraft: V. M. Petlyakov *Пе-2*, S. A. Lavochkin *Ла-7Р* and *120Р*, A. S. Yakovlev *Як-3*, P. O. Sukhoi *Су-6* and *Су-7*. A. G. Vasilchenko, A. S. Palchikov, V. L. Rastorguyev, and A. V. Davydov were among the test pilots. The *РД-1Х3* and *РД-2* engines were tested for state qualification, the *РД-3* was static tested. These engines were developed by the GDL—OKB.

The extensive experience gathered during the creation of this family of rocket engines and aircraft power units was fundamental for the development, by the GDL—OKB, of powerplants for all rockets which have served for conquest of space up to 1969.

РД-107, РД-108 (*RD-107*, *RD-108*). *РД-107* is the liquid-propellant engine of the 1st stage of the *Vostok* launch vehicle. Its parameters are: controlled



РД-108 high-power liquid-propellant rocket engine of Soviet design (GDL-OKB, 1954—57). Propellant, oxygen + kerosene. Thrust in vacuum, 96 tons. Specific impulse, 315 sec. This engine powered the 2nd stage of the launch vehicles used to send into space man-made satellites, *Vostok* and *Voskhod* spaceships, and all interplanetary stations of the *Luna*, *Venyera*, and *Mars* series.

1—attitude control combustion chambers (four); *2*—gimballing mechanism and oxidizer supply assembly; *3*—oxidizer pipelines of attitude control chambers; *4*—fuel pipeline of attitude control chambers; *5*—mockup brackets (not present in structure); *6*—main combustion chamber; *7*—oxidizer pipeline; *8*—thrust frame; *9*—inlet connection of fuel pump; *10*—inlet connection of oxidizer pump; *11*—body of heat exchanger on turbine; *12*—gas generator; *13*—main fuel valve; *14*—fuel manifold.

thrust in vacuum, 102 t; specific impulse, 314 s; gas pressure in combustion chamber, 60 at ab; gas expansion ratio, 150; oxidizer, LOX; fuel, kerosene. This is a four-chamber engine with 2 thrust chambers gimballed for flight-path control (they reduce the total specific thrust by 1 s). The engine comprises 1 turbo-pump unit with 2 main pumps for feeding the oxidizer and fuel and 2 auxiliary ones driven through a gearbox and delivering hydrogen peroxide to the gas generator and liquid nitrogen for propellant tank pressurization; a gas generator; a set of automation devices and controls with drives; a heat exchanger for the gasification of nitrogen by the turbine exhaust gases; an automatic cartridge ignition device; and a thrust frame for assembling the engine and attaching it to the rocket. It is remarkable for high specific impulse and reliability. Employed on the launch vehicle are 4 *РД-107* engines. See Fig, p. 354.

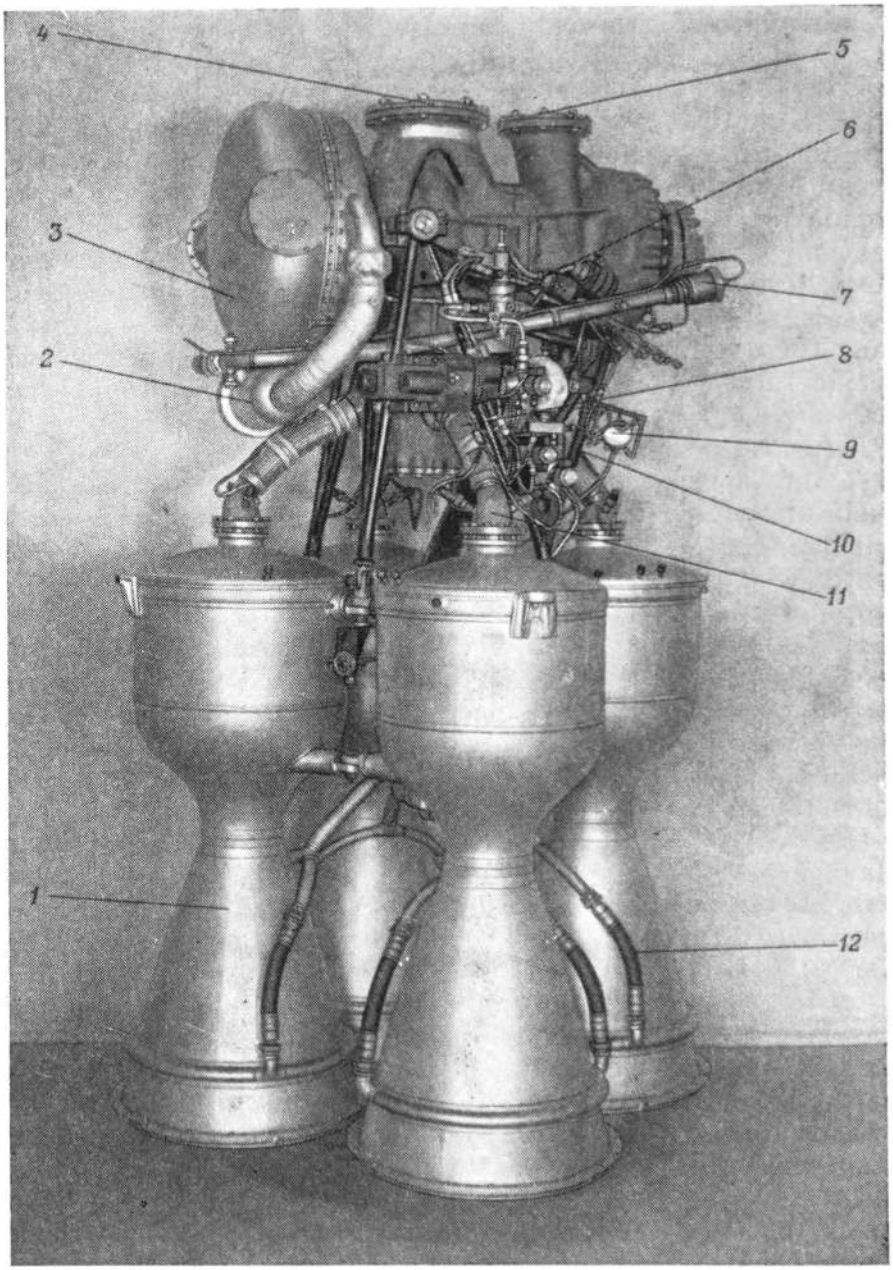
RD-214

The *РД-108* liquid-propellant engines power the 2nd stage of the *Vostok* launch vehicle. The engine's characteristics are: controlled thrust in vacuum, 96 t; specific impulse, 315 s; gas pressure in combustion chamber, 52 at ab; gas expansion ratio, 150; propellant, same. As different from *РД-107*, it has 4 control chambers, different automation devices, and frame. It is fired on the ground simultaneously with the engines of the 1st stage. A single *РД-108* engine is installed on a launch vehicle. These engines were developed in 1954—1957 by the GDL—OKB. They were used to orbit the first Soviet satellites and the first manned spaceships. Various versions of the *РД-107* engine were used in the past 13 years on a number of launch vehicles designed for launching automatic and manned space bodies into near-Earth orbits and trajectories to the Moon, Venus and Mars.

РД-119 (*RD-119*). The liquid-propellant engine of the 2nd stage of the *Cosmos* launch vehicle. Its parameters are: controlled thrust in vacuum, 11 t; specific impulse, 352 s; gas pressure in combustion chamber, 80 at ab; gas expansion ratio, 1350; oxidizer, LOX; fuel, unsymmetrical dimethyl hydrazine. The engine comprises a thrust chamber with an automatic cartridge ignition system; a turbopump unit; a monopropellant gas generator in which unsymmetrical dimethyl hydrazine is decomposed; a cartridge starter; a set of automation devices and controls with drives; a system of fixed control nozzles with gas distributors; a thrust frame for attaching the engine to the rocket. Extensive use of titanium has been made in the structure. An outstanding feature of the *РД-119* engine is a very high specific impulse, the highest for liquid-propellant engines of the oxygen class operating on high-boiling fuels. It was designed in 1958—1962 by the GDL—OKB (see Fig. on page 355).

РД-214 (*RD-214*). The liquid-propellant engine of the 1st stage of *Cosmos* launch vehicle. Controlled thrust in vacuum, 74 t; specific impulse, 264 s; gas pressure in combustion chamber, 45 at ab; gas expansion ratio in nozzle, 64; oxidizer, based on nitric acid; fuel, products of kerosene processing. The engine posseses the highest thrust and specific impulse among the known engines of the same class burning a nitric-acid oxidizer and a hydrocarbon fuel.

РД-214 is a four-chamber engine, it has a single turbopump unit comprising a turbine, a centrifugal pump for oxidizer and another for fuel, and



РД-214 four-chamber engine of Soviet design (GDL — OKB, 1952—57). Propellant, nitric acid + hydrocarbon. Thrust in vacuum, 74 tons. Specific impulse, 264 sec. Pressure in combustion chamber, 45 at ab. Gas expansion ratio in nozzle, 64.

1—combustion chamber; *2*—gas generator; *3*—turbine; *4*—oxidizer pump (inlet); *5*—fuel pump (inlet); *6*—air reducer; *7*—hydrogen peroxide pressure regulator; *8*—oxidizer-feed pipe; *9*—pressure relay; *10*—frame; *11*—oxidizer shut-off valve; *12*—fuel-feed pipe

a pump for hydrogen peroxide fed into the gas generator. Products of catalytic decomposition of hydrogen peroxide evolve from the gas generator and drive the turbine. Steam-gas from the turbine is ejected through the nozzle, thus producing an additional thrust. The thrust chamber is cooled by fuel regeneration and internal film formed by periphery injectors of the injector head. Chemical ignition system makes use of a starting fuel forming a hypergolic couple with the major oxidizer; the starting fuel is poured into the fuel manifold before the fuel pump. No preliminary stage of starting is necessary. In flight, thrust is controlled by adjusting the flow rate of hydrogen peroxide directed into the gas generator. Prior to cut-off the engine is slowed down to the final stage of burning. Gas vanes permit to control thrust vector.

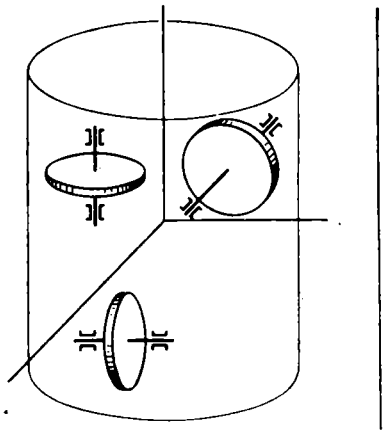
An early development of the GDL—OKB (1952—1957), the *РД-214* engine has flown since 1957 when it powered a prototype *Cosmos* launch vehicle.

REACTION ENGINE (engine of direct reaction). An engine developing thrust by ejecting a JET EFFLUX. The kinetic energy of the jet results from transformation of some other type of energy (thermal, chemical, nuclear, electrical, solar, etc.). A reaction engine combines the engine proper and the propelling agent. The notion of reaction engine includes all types of engines of direct reaction (ROCKET ENGINE, JET ENGINE, COMBINATION ROCKET ENGINE, etc.).

REACTION FORCE. The force of reaction of a jet of gases (or some other working fluid) flowing from an engine. It is the resultant of all the gas-pressure forces on the inner surfaces of a rocket engine thrust chamber.

REACTION TURBINE. The turbine in which the potential energy of the working fluid is transformed into kinetic energy both in the nozzle and on the blades of the turbine rotor. Low-pressure high-speed reaction turbines are usually employed in the turbo-pump units of rocket engines.

REACTION VEHICLE. The generic term for a vast class of vehicles whose propulsion is based on the principle of direct reaction. Some examples are space vehicles, aerospace planes, ballistic missiles, etc.



REACTIVE GYRATING MASSES. Inertial actuators of a system of orientation employing flywheels (gyroscopes) having a controlled speed of rotation. Changes in the speed of rotation (acceleration or slow-down) of the flywheels produce reaction torques that are utilized as control moments affecting the motion of the spacecraft. In most cases, 3 gyrating masses are used for developing control moments with respect to each of the 3 axes of the spacecraft.

REACTOR OF NUCLEAR ROCKET ENGINE. The nuclear reactor which emits thermal energy to heat the working fluid of the rocket engine.

Rear-end unit

REAR-END UNIT. The module of a rocket or a rocket stage housing the engine and some elements of the rocket's equipment (part of the control equipment, space-borne propellant loading fittings, etc.). The rear-end unit is a thin-wall frame structure, often consisting of a shell with longitudinal and transverse stress-bearing elements. Thrust ring of the engine frame usually forms a junction with the front frame. The rear-end unit ends with a butt-end frame on which in most instances the control organs (gas vanes or vernier rocket engines) are mounted, as well as the stress-bearing units for installing the rocket on the launcher (or for joining with the preceding rocket stage in multi-stage rockets). If the rear-end unit carries stabilizers, their ribs are secured to the stress-bearing elements. The hatches provided in the rear-end unit skin give access to various units and fittings.

RECEIVER ROOM. A structure provided with equipment for the receival, storage, and supply of compressed gases. The receiver room houses a sectionalized batteries of cylinders holding compressed air, nitrogen, or helium; the battery cylinders within a section are joined together by a common manifold. The section inlet and outlet pipelines are brought up to a pneumatic control board accommodating the control valves, filters, gas pressure reducers and monitoring instruments. Panels for supervising the fulfilment of operations involved in the receival and supply of compressed gases are installed in special rooms. Remote-control systems for the filling, storage, and supply of compressed gases to consumers are employed. The gases are stored in the receiver room at a pressure of 200 to 400 at.

RECOMBINATION. Formation of molecules by the re-union either of their fractions produced on DISSOCIATION or of free radicals.

RECONDENSATION of cryogenic propellant. Converting the gaseous propellant, evaporating in the launch vehicle tanks on ground, back into liquid to make up for the losses of CRYOGENIC PROPELLANT. As much as several tons of propellant may be lost, the losses depending on the surface area of the tanks, their thermal isolation and the time the launch vehicle is kept on the launch pad with its tanks filled. Recondensation is one of the methods to control the losses of costly cryogenic propellant.

RECONNAISSANCE SATELLITE. See MILITARY EARTH SATELLITE.

RECURRENT MAGNETIC DISTURBANCES. Disturbances of the Earth's magnetic field exhibiting a tendency to recur at 27-day intervals (the period of the Sun's rotation), which is one of the proofs of the corpuscular theory of geomagnetic storms.

RECYCLING OF SUBSTANCES. The cyclic process of conversion and transportation of substances within a spaceship for purposes of reproduction, from metabolic by-products, of the food, water, oxygen, etc. necessary for man and the other members of the BIOCOMPLEX. Recycling of substances within a spaceship can be based on biological synthesis of organic substances in the primary (autotrophic) links of the LSS with subsequent destruction of these substances in the heterotrophic links, or on physico-chemical processes of controlled synthesis of proteins, fats, and carbo-hydrates from wastes mineralized to more or less simple substances (mineral salts and water). The principles and a number of design variants have been developed for LSS based on biological recycling of substances. These systems include

both functional links that cultivate various groups of higher plants, algae, lower or higher animals, and certain physico-chemical processes. The energy supply to a space-borne LSS can be from solar radiation or a source on board the spaceship (electric or nuclear cells, etc.).

RECYCLING OF WATER. A cyclic process ensuring multiple use of a constant amount of water in the LSS of a spaceship. It is one of the approaches towards a water supply system based on recovery processes. It is characterized by minimum initial amounts of water recovered repeatedly by various biological and physico-chemical methods. For short-duration flights, physico-chemical methods are preferable. In these cases human urine and atmospheric moisture condensate are regenerated; sorption, distillation and catalytic methods are most promising. With extension of space-flight duration water recycling begins to involve such sources of water as sanitation, transpiration, and process water, as well as by-products containing moisture. In extended space flight, biological methods of water recovery, such as micro-biological oxidation of organic substances contained in the metabolic by-products or use of lower and higher AUTOTROPHS will play an important part. The physico-chemical methods in this case serve for an additional purification of water generated in various links of the biocomplex and in the emergency recovery system. Water recycling makes it possible to considerably reduce the launching weight of the LSS of a spaceship.

REDUCED PERFORMANCE OF SOLID PROPELLANT. An energetic characteristic of a rocket propellant, the product of the combustion temperature at constant pressure multiplied by the gas constant of the combustion products. Specific impulse is proportional to the square root of the reduced perfomance. Specific impulse characterizes the energetic quality of the propellant more exactly.

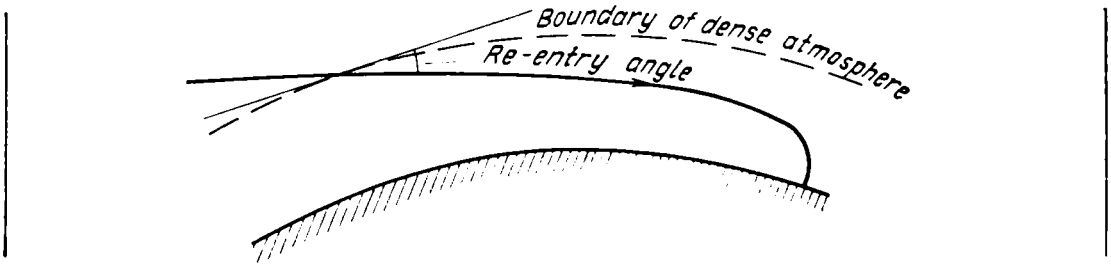
REDUCED VELOCITY. Ratio of the flow velocity to the speed of sound in the THROAT SECTION OF NOZZLE. An important parameter of the nozzle gas dynamics. The reduced velocity can be expressed in MACH NUMBERS.

REDUNDANCY (standby). The reserve, on board a spacecraft or rocket, of elements, units, instruments, etc., aimed to replace any given piece of equipment if it fails in service. This is one of the methods of improving the reliability of a spacecraft or rocket. In flight, a given redundant unit may remain switched on and ready (so-called "hot" reserve), or may remain switched off ("cold" reserve). In either case, the unit is put into operation as soon as a failure occurs in the piece of equipment it backs up. Indication of a failure and cut-in of the standby unit may be accomplished through the telemetry system and radio command communication line (from earth), by a spaceman on board, or by the automatic failure detection system. Apart from the direct backup of some piece of equipment, use is made of means for functional standby which provides that the functions of a given system may be taken over by another system, e.g., a manual control may take over or override an automatic control.

RE-ENTRY in an atmosphere. The motion of a spacecraft (re-entry body) in the dense layers of the atmosphere of a planet prior to landing on the surface of the planet. In cases when the velocity of the spacecraft has not been greatly reduced by retro-rockets, the re-entry velocity is very high

and may approximate the 1st cosmic velocity for low-orbit satellites or the 2nd cosmic velocity and higher for spacecraft approaching the planet after a long-distance flight; the speed is slowed down in the atmosphere due to the effect of the resulting DRAG, this process being accompanied by the arise of considerable g-loads and intensive aerodynamic heating. The re-entry of a manned spaceship imposes several limitations connected with its structural strength and heat resistance, as well as with human tolerance to g-load. The total quantity of acquired heat, the maximum rate of heat influx, the maximum overloads and their duration shall not exceed permissible levels. Simultaneous observance of all these limitations is the more difficult the higher the initial velocity of the re-entering spaceship. At speeds much greater than the 1st cosmic velocity, this can be achieved only by controlled descent or gradual deceleration by multi-pass atmospheric braking.

RE-ENTRY ANGLE. The angle between the direction of flight of the spacecraft (or other re-entry body) and the local horizon of the planet at the moment of entry of the spacecraft into the dense layers of its atmosphere.



The distance of flight to the point of landing as well as the AERODYNAMIC HEATING and overloading of the spacecraft during its travel through the atmosphere are greatly dependent on the re-entry angle and, consequently, the latter has to be closely controlled. The re-entry angle is not more than a few degrees (3—5° or less) for all types of spacecraft that are not provided with retro-rockets; the thermal and aerodynamic overloads become intolerable at greater values of the re-entry angle.

RE-ENTRY BODY. The part of a spacecraft that is designed for decelerated descent and for making a landing on the surface of the Earth or another celestial body. The re-entry body of a manned spaceship is a capsule housing the crew; in the case of an automatic spacecraft it is the instrument container. The re-entry body usually carries some of the spacecraft equipment, notably the radio communication apparatus, the LSS, the spacemen's seats and control desk, elements of the automatic control and temperature control system, etc. Re-entry bodies carry also landing control system. The outside surface of the re-entry body moving through an atmosphere is given a thermal-protective coating. The shape of a re-entry body may be spherical, conical or other. The aerodynamic shape and centre of gravity are selected so as to ensure the aerodynamic stability of the spacecraft. A re-entry body may follow a BALLISTIC TRAJECTORY or a gliding trajectory.

RE-ENTRY CORRIDOR. The range of flight altitudes of a re-entry body travelling at the SECOND COSMIC VELOCITY, within which the "capture" of the

body by the atmosphere is ensured with a subsequent landing in a specified point of the Earth. The margins of the re-entry corridor are selected proceeding from the need of decelerating the re-entry body to FIRST COSMIC VELOCITY the first time it dips into the atmosphere. The minimum weight of the heat shield and the re-entry overloads are other determinants. The range is about ± 10 km from the nominal re-entry altitude.

RE-ENTRY WITH ATMOSPHERIC BRAKING. The descent of a spacecraft to the surface of the Earth or some other planet, during which the speed of the spacecraft with respect to the planet is slowed down due to the aerodynamic drag arising in the course of its travel through the atmosphere. Atmospheric braking is recommended for landing spacecraft on the surface of a planet having a sufficiently dense atmosphere, e.g., on the Earth. In such cases it is the usual practice to land the re-entry body rather than the entire spacecraft. Aerodynamic braking decelerates the RE-ENTRY BODY to a speed of 150—250 m/s. Further deceleration and landing is accomplished by means of parachutes or other systems. A ballistic or gliding descent may be envisaged for the re-entry.

REFERENCE POINTS. Celestial bodies used for the orientation of spacecraft or the solution of navigational problems by astronomical methods. The Sun, planets, or the brightest stars may serve as reference points. A suitable reference point is the Canopus of the Southern hemisphere located near the perpendicular to the plane of the ecliptic; the angle between the straight lines joining the spacecraft with the Sun and Canopus changes very slightly in the course of interplanetary flights that are made, as a general rule, within the plane of the ecliptic. This circumstance allows to simplify the design of star sensors. The use of faint stars as points of reference presents certain technical difficulties (see SEARCH OF REFERENCE POINTS).

REFRACTION OF RADIO WAVES. Distortion of the path of radio waves on their passage through physically heterogeneous regions. Refraction occurs, for example, in the atmospheres of planets. Refraction must be taken into account when measuring the coordinates, speed and distance of spacecraft and can be used as indirect means for investigation of the atmospheres of planets. Atmospheric refraction of radio waves is function of time.

REFRIGERATION CENTRE. A set of refrigeration plants, heat exchangers and pump plants for ensuring THERMOSTATIC CONTROL of propellants and space centre compartments at the launching site. The refrigeration centre is operated by remote control from consoles at the control centre. Refrigerating and heating centres have electric or steam heating devices that heat air and liquid heat-carriers.

REFUELLING. Additional fuelling of launch vehicles at low flow rates in order to obtain the amount of propellant in the tanks, prescribed in the flight assignment. It is performed in the following cases; when the flight assignment has been changed and a greater supply of propellant is required; prior to launching the vehicle that had long stood erected and fuelled on the launcher, which resulted in evaporation losses of the propellant from the rocket tanks; at the end of the main filling process performed at high flow rates, in order to avoid hydraulic shock on cutting off the supply of propellant and for accurate filling of the tanks with the required amount

Regennera-
tion
controlling
device

of propellant. The main filling process may be performed with volume flow rate of the propellant of up to $10 \cdot 10^3$ l/min, while in additional filling it is one order of magnitude lower.

REGENERATION CONTROLLING DEVICE. An automatic device used in the air regeneration systems to control the rate of oxygen regeneration and thereby control pressure in the sealed spaceship cabin. In the *Vostok*, *Voskhod* and *Soyuz* spaceships, the air was regenerated with superoxides of alkali metals, additional air driers and carbon dioxide absorbers. The concentration of carbon dioxide in the cabin was controlled by selection of specific rate of ventilation via carbon dioxide absorbers. The air humidity was maintained by forcing the air through main and additional moisture absorbers. This regeneration system increased or reduced the total air pressure in the cabin by increasing or reducing the partial oxygen pressure.

REGENERATIVE COOLING. See COOLING OF ROCKET ENGINE.

RELIABILITY. The ability of a space vehicle to perform the assigned tasks under certain operational conditions within a specified period of time or accrued service time. The reliability of spacecraft equipment or structure is of vital importance due to specific conditions of rocket or space flight: effects of space factors, impossibility of replacement or repair, etc. No failures of equipment or structure, in this case, are permissible as they may lead to an accident.

High level of reliability can be ensured by a complex of measures taken at the stages of design, production, and testing, as well as during the flight of a space vehicle. The main methods of enhancing the reliability of a space vehicle are: improvement of production quality; careful selection and accurate implementation of manufacturing processes at every stage of production; increasing the reliability of individual components (radio and electrical elements, fittings, certain assemblies, materials, etc.) and correctly choosing their mode of operation; special testing of systems and assemblies in simulated space flight environment and service-life testing to confirm the claimed reliability; using stand-by and redundant elements and space-borne systems; applying automatic circuits for detection of element failures in the space-borne systems and switching over from faulty elements to healthy ones; monitoring the in-flight operation of space-borne systems by means of telemetry or by the crew, with the view to perform actions necessary for successfully carrying on the flight in spite of failures of individual elements (use of stand-by systems, manual control, etc.).

RELIABILITY OF LAUNCH COMPLEX is characterized by the probability of failure-free operation within a given period of time. To estimate the reliability of an aggregate system, reliability structural diagrams are drawn up showing reliability data for the system ingredients. Data for determining the reliability of individual elements are obtained by statistical accumulation and study of all cases of their failure in operation. Certain reliability characteristics of the entire launch complex may be determined, such as the probability of a launch vehicle preparation for launch within a given interval of time or the probability of failure-free operation of the launch complex units and systems during the launch and lift-off of the launch vehicle. Estimation of the launch complex reliability is a difficult problem

and is made even more so by the fact that a launch complex includes unique systems and units which provide no possibility of quickly collecting statistical data on the rate of failures. At the same time the problem of launch complex reliability is extremely important in view of the continuous sophistication of the equipment and the direct relation between the successful firing of the launch vehicle, the safety of the spacemen, and the reliability of the launch complex.

RELIABILITY OF ROCKET ENGINE is assessed quantitatively by a number of criteria: probability of faultless operation, factor of utilization, readiness factor, mean time to failure, etc. One of the most widely used criteria of rocket engine reliability is the probability of faultless operation of the rocket engine, i.e., the ability of any randomly selected rocket engine of those manufactured and maintained to specification to ensure the accomplishment of its mission. A rocket engine's reliability is ensured by its perfect design, high quality of manufacture and maintenance. Reliability of a rocket engine is a characteristic which cannot be measured directly and is assessed by statistical methods of probability according to the results of testing of the rocket engine and its components, as well as of similar components of other rocket engines within a wide range of changing external and internal factors. The methods of testing and of appraising the reliability of a rocket engine are determined by the designation, type, propellant used, design peculiarities and parameters of the rocket engine.

RELIEVING INERTIAL ACTUATORS of the orientation system. See SUPPRESSION OF KINETIC MOMENT.

REMOTE CONTROL OF PROCESS OPERATIONS. Space centre equipment comprising control units mounted in the junction box supports, a push-button station and cable connections. It ensures remote control of the launcher and the transporter-erector unit, or the transporter-erector dolly and the erector, while they erect, remove and vertically align the launch vehicle; it also controls maintenance operations on these items of equipment.

REMOTE CONTROL SYSTEM. A multi-channel electric wire system of a space centre provided for recording and checking the variables determining the degree of spacecraft readiness for launching. The system gives a notion of temperature and pressure in various sections of the spacecraft, the positions of operating elements of the pneumatic and hydraulic systems of the rocket powerplant, sealing of instrument compartments, etc. The number of parameters checked by the remote control system may vary from a few tens to several hundreds.

REPEATED STARTING OF ROCKET ENGINE. A number of consecutive firings and cut-offs of a rocket engine. Restartability is an important property of aircraft and some space rocket engines; it is yet to be achieved for solid-propellant engines.

REPLENISHER. A servicing unit, periodically making up for the evaporation losses in the cryogenic propellant tanks of a space vehicle. It comprises a heat-insulated tank, an automatic replenishment control system and a set of pipes with shut-off and regulating fittings and hoses. The propellant is pump- or pressure-fed. The control system of the replenisher is connected with the system of propellant level control in the launch vehicle tanks and

Replenishment

ensures automatic starting and stopping of the make-up operations. As the propellant level drops below normal due to evaporation, the replenisher control system receives the command to switch on the make-up mechanism, and the propellant is delivered into the vehicle tank at a low rate; as soon as the propellant level reaches the predetermined level, a command signal turns off the supply of the make-up propellant. Before the take-off, the replenisher is disconnected from the launch vehicle.

REPLENISHMENT. Periodical topping of the space vehicle tanks with cryogenic propellant by means of a replenisher to compensate for the propellant losses due to evaporation while the space vehicle is kept filled on the launcher.

RESCUE OF SPACEMEN AND SPACESHIPS is the subject of international law agreements concerning the rescue of spacemen and spaceships in cases of emergency. Scientists and engineers are hard at work on means for rescuing spaceship crews in emergency situations at all stages of space flight up to the re-entry and recovery on land or sea. In the event of a forced landing on the Earth, the crews will have a special portable emergency kit containing everything necessary for man, *viz.*, a radio set, a food store, water, a sea water chemical distiller, a pneumatic boat, etc. The spacemen should be discovered, given the necessary aid and helped to return to their mother-country.

All this is envisaged in Article V of the 1967 AGREEMENT and in the international agreement on rescue of spacemen and return of spacemen and objects launched into space in case of emergency, disaster or forced landing (1968). In the course of further conquest of circumterrestrial space, the Moon, and other celestial bodies, an ever-growing importance is acquired by the problem of mutual aid by spacemen from different countries.

RESIDUAL ANGULAR VELOCITY. (1) The angular velocity of a spacecraft after termination of angular velocity suppression. In many cases the residual angular velocity must be strictly limited, e.g., in the GRAVITATIONAL SYSTEM OF ORIENTATION it shall not exceed a few hundredths of an angular degree per s. (2) In manual orientation system it is the angular velocity below the threshold of response of space-borne sensors, which is equal to the maximum velocity that the spacecraft may have when the control handle is not used.

RESTRICTED CIRCULAR PROBLEM OF THREE BODIES. The problem of motion of a particle of zero mass under the attraction of two material particles describing circular orbits about their common centre of mass. A problem of this kind is encountered, for example, in studies of the motion of an asteroid or comet under the influence of the attraction of the Sun and Jupiter, the Jovian orbit, to a first approximation, being considered as circular. The problem is also directly related to investigations of the motion of a spacecraft in the Earth—Moon system. No rigorous solution of the restricted circular problem of three bodies suitable for computing the coordinates of a moving body has yet been obtained, but in celestial mechanics approximate methods have been elaborated that enable one to find a sufficiently exact solution of the problem for many particular cases.

RETRO-ROCKET ENGINE. A rocket engine for decelerating a spacecraft. The thrust of the retro-rocket is directed in reverse to that of the sustainer

engine and against the flight velocity vector. It is used for descent from orbit during landing, as well as for slowing down separate stages of a multi-stage rocket after their separation. Both liquid and solid-propellant engines are used as retro-rockets.

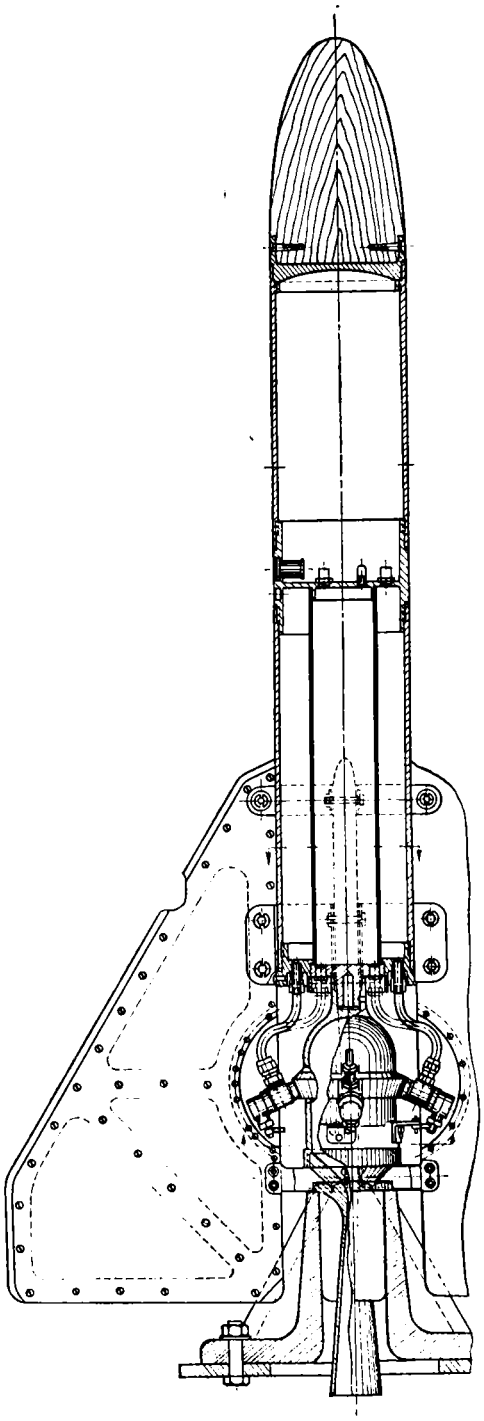
REVERSE PROBLEMS OF SATELLITE METEOROLOGY. Determination of meteorological parameters (temperature, pressure, humidity, etc.), structural characteristics and composition of the Earth's atmosphere by Earth radiation measurements. Most informative is EARTH RADIATION, where measurement can supply data for determining the TEMPERATURE OF UNDERLYING SURFACE and cloud height, for thermal sounding of the atmosphere and for solution of other reverse problems. There are great prospects for meteorological interpretation of measurement data of the Earth's microwave thermal radiation into outer space. Earth UV radiation is an indicator of the content and vertical distribution of ozone in the atmosphere.

RIGHT ASCENSION. A coordinate in the equatorial system of CELESTIAL COORDINATES: the arc of the equator measured in the direction opposite to the diurnal rotation of the CELESTIAL SPHERE from the point of vernal equinox to the circle of declination of the celestial body. This is the dihedral angle between the circle of declination, passing through the vernal equinox, and the circle of declination of the celestial body. It is measured from 0° to 360° or from 0 to 24 h.

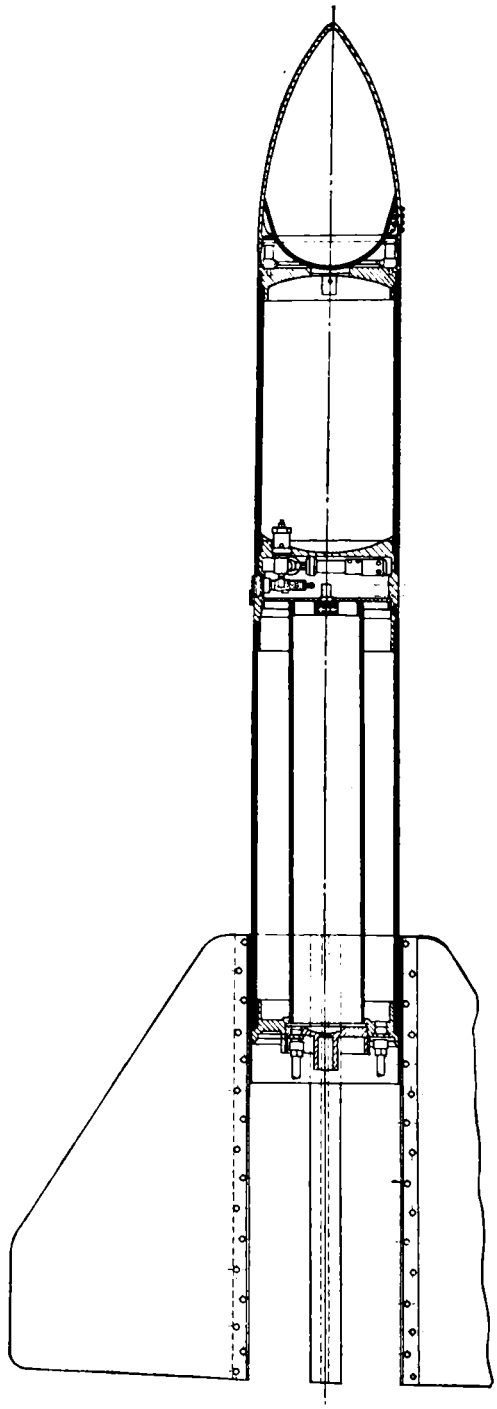
РЛА (*RLA*). Abbreviation for Russian words for "reaction vehicle". Experimental rockets developed in 1931—1933 by the GDL.

РЛА-1 was an unguided rocket for vertical flights to altitudes of 2—4 km. It was designed for flight-testing of liquid-propellant engines of 250-kg thrust and for proving launches from launching pads without guides. The rocket's length was 1880 mm, body dia, 195 mm. The propellant was pressure-fed by compressed nitrogen from pressure accumulator, without pressure reducing valve. The fuel (kerosene) tank was located concentrically inside the oxidizer (nitric acid) tank. The rocket had a steel body with wooden nose cone and tail unit; it was manufactured by machine-shops of the Leningrad Monetny Dvor (mint) and in other places. The rocket was designed and manufactured. Powered by an *ОРМ-52* rocket engine, it passed a pilot series of bench tests in 1933.

РЛА-2 differed from *РЛА-1* in that it had a duralumin head housing meteorological instruments fastened to a standard parachute used by pilots; the parachute was deployed automatically Other distinctions were an accessory compartment in the middle part of the rocket, containing air pressure reducer, and a tail unit made of duralumin. The procedure of parachute packing into the *РЛА-2* head was excercised, and the parachute deployment timer and the accessory compartment were tested on bench in 1933. In this connection the structure of the *РЛА-1* was re-assembled to resemble *РЛА-2*: the accessory container and the duralumin tail unit were introduced, after which the rocket was bench-tested in late 1933. To start the engine, a cotter pin was to be pulled out, which released a spring, and the latter opened a pneumatic valve separating the presure accumulator from the propellant tanks. *РЛА-1* and *РЛА-2* were not flight tested.



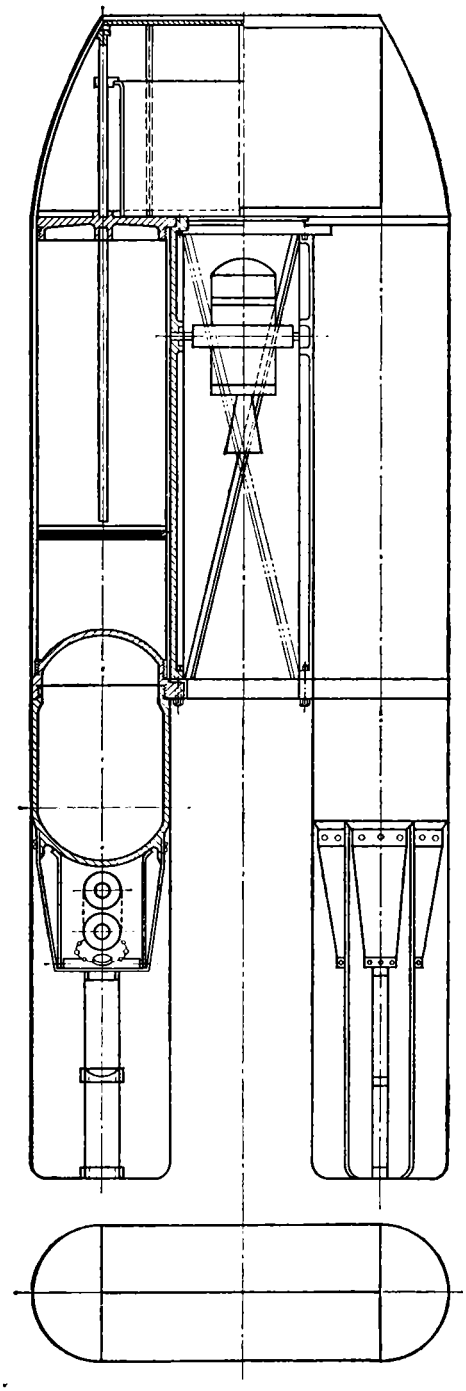
РЛА-1



РЛА-2

РЛА-3 was a guided missile. It differed from *РЛА-2* in having an instrument compartment housing two Obry gears with air-driven gyros (the gears were taken from a naval torpedo). Commands from the gyros, via pneumatic servodrives and mechanical pull rods, were directed to two pairs of aerodynamic rudders in the tail unit. The rudders were shaped to a Munk profile which caused the least displacement of the centre of pressure when rhe rudders were reset. The manufacture of *РЛА-3* was not finished in 1933.

РЛА-100 rocket was designed for vertical flights to altitudes of up to 100 km. Its lift-off weight was 400 kg, including 250 kg of a nitric-acid oxidizer, 20 kg of the engine, and 20 kg of payload. The engine was capable of a thrust of 3000 kg and a burning time of 20 s. The rocket comprised two bodies with a common head. To achieve rocket stabilization in flight, the engine was gimbaled above the rocket's centre of gravity and stabilized directly by a gyro. Gimbal joints were made hollow and sealed in journal to provide propellant access to the engine. A parachute-borne payload of meteorological instruments and a system for payload ejection into the atmosphere were packed in the rocket's head; the bottom part of the body housed pressure accumulators loaded with compressed nitrogen for propellant feed to the engine; the upper and middle tanks were intended for oxidizer and fuel, respectively; both the tanks and the pressure accumulators were made of high-strength steel. The bottom parts of the bodies carried duralumin tail unit, thus displacing the centre of air pressure below the centre of gravity of the rocket. A specially designed movie camera with a timer was mounted on a tail cone to record the flight path. A launcher with guides was to be employed. Prior to launch, the engine was oriented as necessary and fixed in the chosen attitude by starting the gyro. The design of *РЛА-100* was over in 1932. An engine-gimballing stand was manufactured in early 1933 for bench-testing of engine stabilization by a gyro and a gas jet. At the time, the tanks were being constructed.



РЛА-100

RNII

When in late 1933 a new department was established in RNII with the responsibility for development of vehicles proper, this department took over the projects of *РЛА-1*, *РЛА-2*, *РЛА-3*, and *РЛА-100*. However, these projects did not make further progress.

RNII. See ROCKET RESEARCH INSTITUTE.

ROCKET. A vehicle which travels due to the reaction force by jettisoning a part of its own mass. Rocket is the main type of vehicles, capable of powered flight through vacuum (see SPACE ROCKET; MULTI-STAGE ROCKET; SPACECRAFT).

ROCKET ALIGNMENT. The spatial orientation of the launch vehicle or of elements of its on-board guidance system, effected before launching to ensure the desired parameters of the powered flight. Rocket alignment includes the operations of azimuth alignment and vertical alignment of the launch vehicle. It is carried out by optical aiming instruments.

ROCKET ASSEMBLY. See SPACE CENTRE.

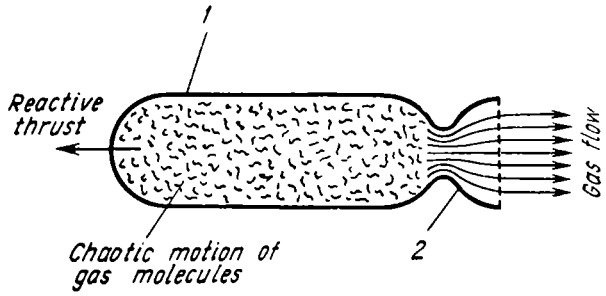
ROCKET-BORNE SYSTEM OF SPACE RADIO COMMUNICATION. A set of radio equipment on board a satellite, spaceship or automatic interplanetary station for exchange of information (telemetry, TV, telegraph, telephone, control commands, etc.) with the Earth or between spacecraft. Wave bands that are only slightly absorbed by the atmosphere are used for the communication. The rocket-borne radio systems comprise antenna feeders, transmitters and receivers, devices for shaping the signal, devices for separating the received signal, and sources of electric power. The systems may also contain equipment for transforming the signals supplied for transmission from different sources of information.

ROCKET ENGINE. A reaction engine (an engine of direct reaction) intended for rocket propulsion and not using any medium (atmospheric air) for functioning. In reaction engines, not only the energy conveyed into the engine (in the chemical, solar, nuclear, or electrical form) is transformed into useful power, i.e., into the kinetic energy of the working fluid, but also motive force of thrust is generated without an intermediate device (propelling agent), by the reaction of a jet of working fluid (usually gaseous combustion products) ejected from the engine. The rocket engine is thus a combination of the engine proper and the propelling agent.

Reaction engines are divided into two main classes depending on whether they use their environment for operation. The first, using the ambient air, are referred to as jet engines, the second, rocket engines. There are also rocket engines that are a combination of both these main types. But it was the rocket engine that was to become the propulsor for space flight because there is no air in space.

Until now only chemical rocket engines are employed, i.e. the ones burning some chemical propellant, using its potential chemical energy. Development is under way in many countries of rocket engines utilising the nuclear, solar, or electric energy. These projects are still at the experimental stage, but some of them are very promising.

There exists a large variety of chemical rocket engines differing in layout, design, propellant and thrust. These engines have a similar working process which takes place under a permanent pressure (although there are also pulse



Schematic diagram of a chemical rocket engine:
1 — combustion chamber; *2* — jet nozzle

rocket engines). All of them have at least two compulsory basic components of integral design, *viz.*, a combustion chamber, where the chemical reaction of combustion, or turning of the propellant into hot gases, takes place, and a nozzle in which these gases expand and flow out at a great velocity. In accordance with this, the working process in chemical rocket engines is comprised of two main stages: first, the chemical energy of the propellant is transformed, in the combustion chamber, into the heat energy of gaseous combustion products, and then the heat energy of the gases transforms in the nozzle into kinetic energy. The ultimate aim of a rocket engine's operation is to make a jet of gases flow at a great speed out of the nozzle creating a reactive thrust. The amount of thrust created by each kg of gases flowing from the engine every second, is called specific impulse. The greater the speed of the gas efflux, the higher the specific impulse and, consequently, the more perfect the propellant and the rocket engine, as it consumes less propellant for the same thrust. To achieve this, the propellant must be more effective, i.e. to be of greater calorific value and to produce more gases, the engine working process should be more perfect in the sense that the biggest possible part of t hepropellant's chemical energy should be transformed into useful kinetic energy of the jet stream.

The "oldest" of all rocket engines is the solid-propellant engine which has been known for centuries. Gunpowder rockets have been long used for fireworks, signalling and combat. The first propellant to be used was gunpowder. In the 1920s it was replaced by smokeless powder and, in recent decades, by more sophisticated propellants. The solid-propellant rocket engine consists of two main parts: the body, or the combustion chamber, where the entire propellant is stored, and the nozzle, i.e. a specially contoured exhaust device through which the hot gaseous products of propellant combustion flow out at a high speed. At present solid-propellant rocket engines are employed mainly for military purposes (rocket artillery). Extensive and successful use of rocket missiles was made in the years of the Great Patriotic War of 1941—1945 when they were fired from *Katyusha* launchers. Non-guided and guided rockets powered by solid-propellant engines serve most diverse purposes: they can be anti-tank and anti-aircraft; they can be mounted on trucks and tanks, on aircraft and warships; and they can be used on the battlefield and for long-range fire. Operational are large-size

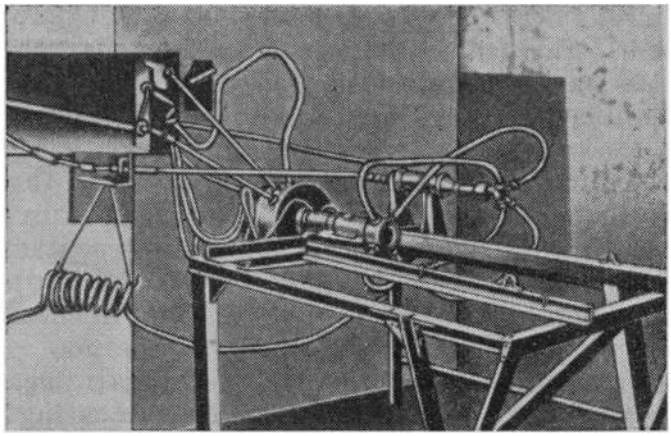
and long-range missiles powered by solid-propellant engines, such as solid ballistic missiles fired by nuclear submarines, and intercontinental ballistic missiles.

The main advantages of solid-propellant engines are that at any moment of long-term storage they are ready for immediate firing, are reliable and simple in maintenance; on the other hand they have some limitations stemming mainly from some properties of solid propellants such as lower efficiency as compared to the best liquid propellants, and a higher cost of the latest, most advanced solid propellants. A major drawback of the solid-propellant engine is that its operation is not easily controlled, and it is a very complex problem to re-start it after cut-off, as well as to alter the thrust, if necessary.

In space flight, solid-propellant engines are sometimes used in the 1st stages of space launch vehicles, which need high-thrust engines. Modern solid-propellant engines can develop a thrust of hundreds of tons while on the design boards are engines with a thrust measured in thousands of tons. The constant improvement of solid propellants, the development of methods for controlling the multitude and direction of the engine thrust, perfection of design aimed at reducing weight and increasing the propellant's share in the engine total weight, all this makes the application of solid-propellant engines promising. But in space flights, where propellant efficiency is determinant, solid-propellant rocket engines are inferior to liquid-propellant ones. Engines firing liquid propellants are called liquid-propellant rocket engines.

In the long-known powder rocket K. E. Tsiolkovsky saw a prototype of the future space vehicle. But first it had to undergo radical improvement, the solid propellant replaced by a liquid one, i.e., a propellant which could be stored in tanks and fed into the combustion chamber in required amounts. This was how the idea of a liquid-propellant rocket engine appeared. Much time passed, however, from the conceptional invention of the liquid-propellant engine to the creation of the first operational motor. Liquid-propellant engines have the highest heat-load indices: the quantity of heat emitted per second in the combustion chamber, the heat flows from gases to the walls, the temperature of the gases, and their velocity. To carry a payload into outer space, a rocket engine needs to operate for a short period of time only. In a matter of minutes, during powered flight, the rocket accelerates to a great cosmic velocity. However, extensive theoretical and experimental studies are required, as well as designing skill, in order to ensure the engine's reliable operation even during this short period of time.

The first Soviet liquid-propellant rocket engine designated *OPM-1* was created in 1930—1931 by the Leningrad Gas Dynamics Laboratory (GDL). In developed a thrust of only 20 kg, whereas modern engines develop thrusts that are thousands of times greater. Engines ranging from *OPM-2* to *OPM-52* were designed in 1931—33. They had a thrust of up to 300 kg and fired propellants in which nitrogen tetroxide, LOX and nitric acid served as oxidizers, while toluene, benzene and kerosene were the fuels. The liquid-propellant engine *OP-2*, designed by F. A. Tsander, underwent firing tests in 1933. It burned a mixture of LOX and gasoline.



Liquid-propellant engine *OP-2* (GIRD, design by F. A. Tsander) on test rig (1933).

The overwhelming majority of all existing liquid-propellant engines burn propellants consisting of two different liquids. In such engines the two liquids, stored in separate tanks, come into contact only after being fed independently into the combustion chamber. Two substances must take part in the chemical reaction of oxidation: the oxidizing substance (oxidizer) and the substance that is oxidized (fuel). It is not imperative to store the propellant components separately, they can be mixed in advance (as is done in the case of solid propellants), or a single liquid may be selected containing both components required for combustion. But the rocket engines with a separate feed of propellant components are more reliable and advanced. The engine design depends on the method used to feed the stored propellant into the combustion chamber. Two methods are widely used: the one is the pressure-fed system, when the propellant is forced out of the tank by a compressed gas, and the other is the pump-fed one, in which special propellant pumps are used driven by a gas turbine. Up-to-date liquid-propellant engines have turbines of tens of thousands hp, which feed tons of propellant per second under high pressure. Gases produced by special gas generators or other gases are used to drive the turbine.

The injection of propellant into the engine combustion chamber is one of the engine's most important operations, determining its perfection. For full combustion each molecule of the fuel must encounter a molecule of the oxidizer, otherwise these molecules will not enter into a chemical reaction and their potential energy will be wasted. It is practically impossible to achieve such an ideal mixing. The efficiency of mixing depends mainly on the design of the injection assembly, i.e. the design and location of orifices through which the propellant components are injected into the combustion chamber.

In liquid-propellant engines the propellant is also used as the engine coolant. This cooling is necessary because the temperature of gases in the

engine usually exceeds 3000° and, sometimes, 4000°C. One of the propellant components, before being fed into the combustion chamber, flows through special ducts in the engine's walls and thus cools from outside the surfaces that come into contact with the hot gases. But in engines with the most heavy thermal loads such regenerative cooling proves to be insufficient and a certain percentage of the propellant has to be fed into the engine through slots or numerous holes in the walls, so as to form a thin protective layer of propellant, a film insulating the walls from direct contact with the gases and the irradiation (this is therefore called the film method). The propellant fired by the liquid-propellant engine should be suitable for use in the cooling system.

In solid-propellant and in some liquid-propellant engines cooling by the propellant can be replaced by a protective ceramic coating or by ABLATION COOLING which considerably simplifies the engine design.

After the propellant has been fed into the combustion chamber, it must be ignited. When the engine is started, this is accomplished by special ignition devices, e.g. electrical, cartridge-type or chemical. They are needless if the propellant is hypergolic, i.e. when self-ignition takes place at the contact of its components. The combustion, once started, is sustained automatically by the flame which is constantly burning in the combustion chamber. Labour-consuming and complicated theoretical and experimental research has to be conducted and great engineering skill displayed to achieve good propellant combustion in a liquid-propellant engine: within fractions of a second the propellant in the chamber must burn out fully, otherwise the engine will be inefficient. Oscillations may occur in the burning gases inside the chamber, which frequently are very difficult to combat. The gases flowing out of the rocket engine must expand in the nozzle so that their velocity would increase to be the maximum possible, the engine thrust and fuel consumption depending on it. To achieve this with the least losses and at minimum weight and size, the nozzle must be carefully profiled. Nozzle design is a very complicated task, since chemical reactions in the gases do not come to an end in the combustion chamber, but continue in the nozzle, too. The efficiency of the entire rocket engine depends to a great extent on the efficiency of the nozzle. Additional difficulties appear when it is necessary to change the direction of thrust, or, as is said, to control the thrust vector, in order to control the rocket's flight. Various methods can be used to change the direction of the gas jet streaming out of the engine. K. E. Tsiolkovsky suggested that special refractory vanes made of graphite be installed in the nozzle exhaust. The entire rocket engine can be gimballed, or only the nozzle made rotatable. Another method used calls for injection of some liquid or gas into the nozzle to deflect the gas stream in the required direction.

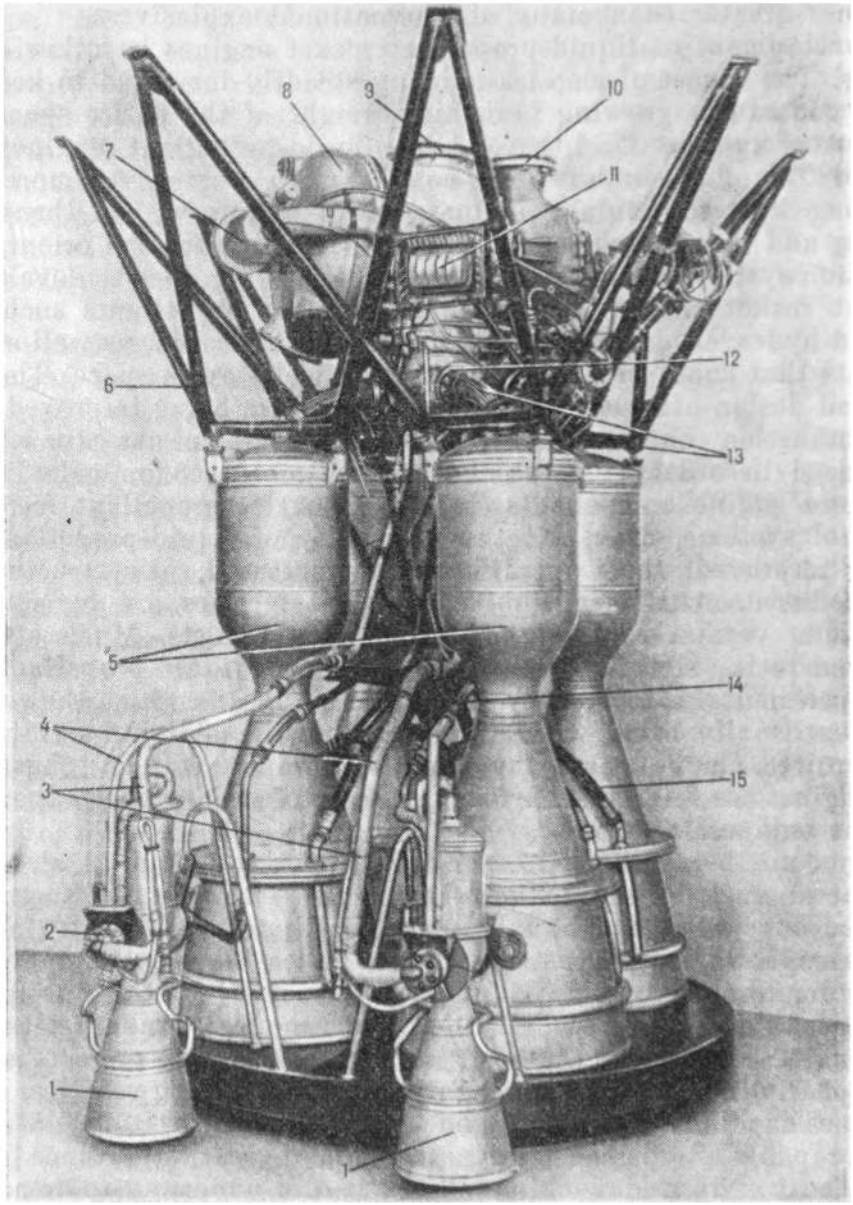
A modern powerful liquid-propellant engine is provided with several sophisticated systems for automatic regulation (e.g., electro-pneumo-pyro-hydraulic), including all kinds of regulators, valves, throttles, transducers, relays, switches, etc. This includes the starting and cut-off systems, systems of thrust regulation and proportioning the consumption of propellant components, propellant tank pressurization, thrust vector control, etc. A malfunction of these systems may cause a failure of the engine proper. A huge amount

of propellant is burned in the engine which creates an explosion hazard many times greater than many of conventional explosives.

The development of liquid-propellant rocket engines is following several directions. The thrust of engines is being steadily increased to keep in step with the constantly growing launching weight of the entire space vehicle. Thus, created in the USA have been liquid-propellant engines with a thrust of 690 t and research is being conducted to create even more powerful ones. Along with super-giant engines, micro-rockets with a thrust of only several kg and even much less are being developed for the orientation and stabilization systems of space vehicles. Much is being done to develop liquid-propellant rocket engines firing highly efficient propellants such as LOX and liquid hydrogen, liquid fluorine and liquid hydrogen, as well as storable propellants that could be used after a prolonged stay in space. The working process and design of liquid-propellant engines are being improved, pressure in the combustion chamber increased, and the degree of gas expansion in the nozzle raised in order to make the engines more economical. The design of the main engine components (injector, nozzle, propellant feed, cooling and control systems, etc.) and the reliability of liquid-propellant engines are being improved, their operational life increased, new structural materials introduced. Auxiliary liquid-propellant engines are being designed: retro-rockets, vernier rockets, and orientation rockets. Much attention is being given to the simplification of the design of liquid-propellant engines. In the experimental stage are several hybrid engines in which the combustion chamber is usually filled with a solid fuel while a liquid oxidizer is fed in the required amounts into the chamber from a tank. The characteristics of such engines are intermediate between those of solid-propellant and liquid-propellant engines.

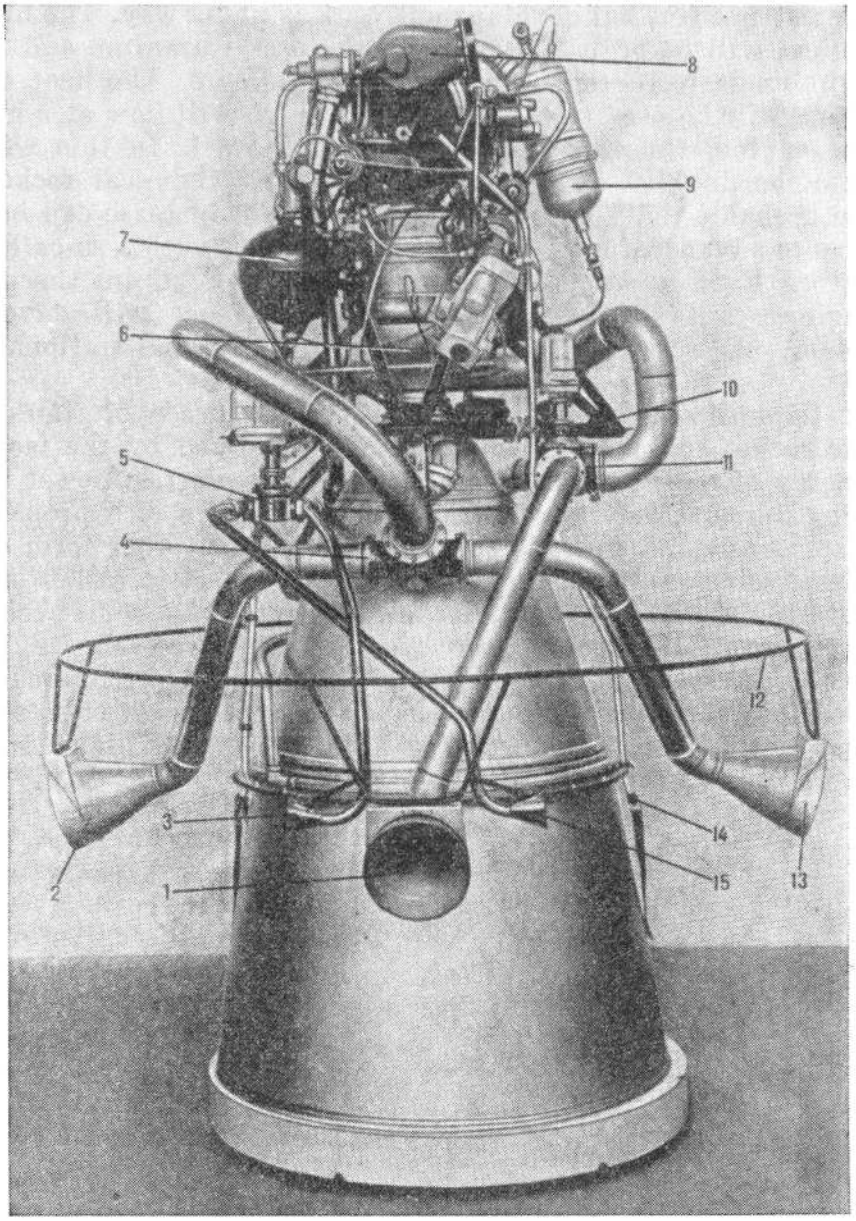
Attempts are being made to use such a working fluid as air in liquid-propellant engines. A space flight begins and ends on the Earth, and its initial and concluding stages take place in the terrestrial atmosphere. The use of atmospheric oxygen instead of an oxidizer stored in tanks reduces the necessary amount of propellant on board. That is why a jet engine can operate much longer than a liquid-propellant one with the same amount of propellant. The jet engine has become the basic aircraft engine, and projects are increasingly appearing suggesting its utilization in space launch vehicles, especially winged ones capable of taking off and landing like conventional aircraft and therefore capable of repeated service, which is of great importance for cutting down the cost of space launchings. Work is also underway to create various combination rocket engines which would combine air-breathing jet engines and liquid-propellant rocket engines, e.g. turbo-rocket or rocket ramjet engines. There is a promise in the idea to use atmospheric air in liquid-propellant engines by means of inducers which suck ambient air into the engine exhaust stream. This air either simply increases the mass of the jet stream, or the atmospheric oxygen serves to afterburn the combustion products of the liquid-propellant engine. In both cases the engine thrust grows while propellant consumption per kg of thrust is reduced.

The use of nuclear energy holds promise of increasing specific impulse and, consequently, the payload launched into space. There is no nuclear rocket



РД-107 high-power liquid-propellant rocket engine of Soviet design (GDL-OKB, 1954-57). Propellant, oxygen + kerosene. Thrust in vacuum, 102 tons. Specific impulse, 314 sec. This engine powered the 1st stages of the launch vehicles used to send into space man-made Earth satellites, *Vostok* and *Voskhod* spaceships, and the interplanetary stations of the *Luna*, *Venyera* and *Mars* series

1—attitude control combustion chambers; *2*—gimballing mechanism and oxidizer supply; *3*—oxidizer pipelines of attitude control chambers; *4*—mockup brackets (not present in structure); *5*—four main combustion chambers; *6*—thrust frame; *7*—gas generator; *8*—body of heat exchanger on turbine; *9*—inlet socket of oxidizer pump; *10*—inlet socket of fuel pump; *11*—combustion-chamber pressure pickup; *12*—main oxidizer valve; *13*—oxidizer manifolds; *14*—main fuel valve; *15*—fuel manifolds.

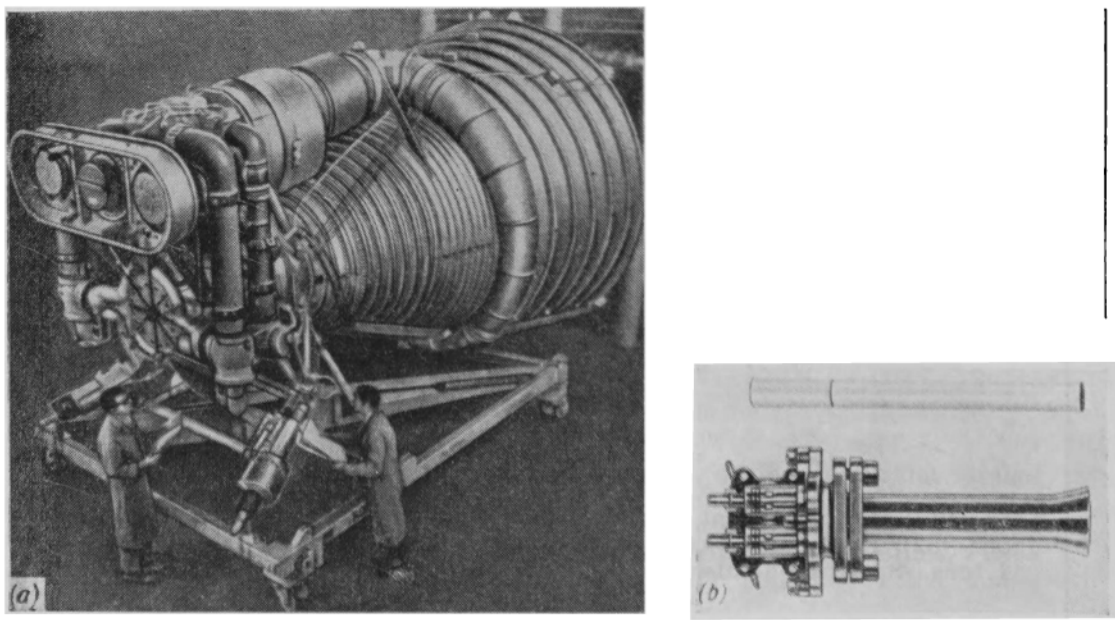


РД-119 liquid-propellant rocket engine of Soviet design (GDL-OKB, 1958—62). Propellant, oxygen + dimethyl hydrazine. Thrust in vacuum, 11 tons. Specific impulse, 352 sec. This engine powers the 2nd stage of the *Cosmos* launch vehicle

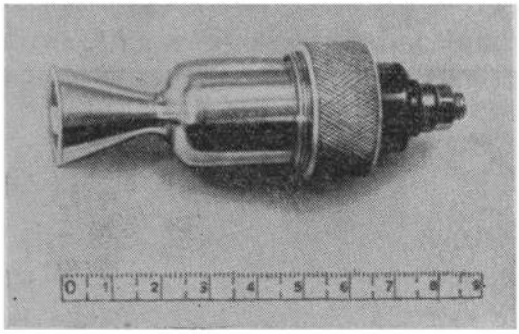
1—pitch control nozzles (the other nozzle is behind the engine); *2*, *13*—yaw control nozzles; *3*, *15* — roll control nozzles (the other pair of nozzles is behind the engine); *4*, *5*, *11*—electrically operated gas distributors; *6*—combustion chamber; *7*—spheric bottle for compressed air; *8*—turbopump unit; *9*—gas generator; *10*—thrust frame; *12*—mounting ring of attitude control system (not present in the structure); *14*—removable plug.

engine in existence yet, but development work is under way. The first nuclear rocket engines will be probably based on the use of uranium and plutonium light-weight nuclear reactors with a solid phase core. The heat emitted in such reactors will be used to heat hydrogen which will flow at a great speed out of the engine, thus creating the reaction thrust. In this way specific impulse can be doubled as compared to the best chemical rocket engines. It is quite probable that another two- or three-fold increase can be achieved by using more advanced nuclear rocket engines, e.g. with a so-called gaseous core reactor. Even greater possibilities are inherent in thermo-nuclear rocket engines, but before they are created science will have to solve the problem of uses of thermo-nuclear energy in stationary power plants.

Specific impulse can be increased tens and hundreds of times by using an electric rocket engine. This engine is characterized by the fact that the kinetic energy of rocket efflux is produced by the electric power applied to the working fluid, rather than by the chemical energy of a propellant. The electrical power, in its turn, is the product of some other form of energy, e.g., nuclear, solar or chemical. That is why any electric rocket engine consists of two main parts, an electric power generator and an accelerator in which the current accelerates the working fluid to very high exhaust velocities. Depending on the accelerator design all electric rocket engines are divided into three main groups: electro-thermal rocket engines in which the current simply heats the working fluid to a very high temperature,



Thrust range of modern liquid-propellant engines is very wide: (*a*) *F-1* engine for *Saturn-5* space vehicle developing a thrust of 680 tons; (*b*) microrocket engine (a cigarette shows the scale) (USA).

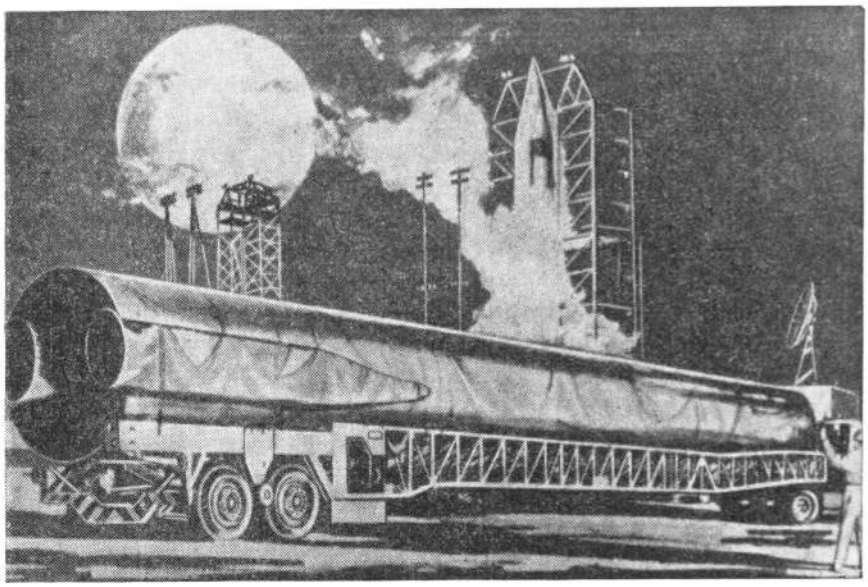


The world's first electrical (electrothermal) rocket engine designed by the Gas Dynamics Laboratory (1929—33).

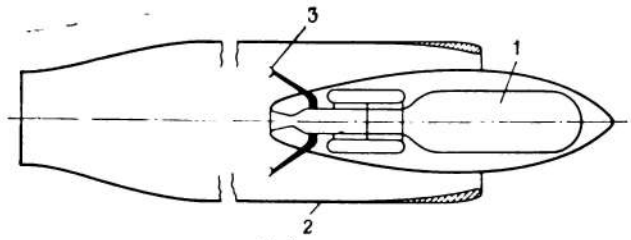
which causes the exhaust velocity to be high; electro-magnetic (or plasma) rocket engines where, apart from heating, the very hot and therefore electrically conductive gas, the so-called plasma, is accelerated by an electromagnetic field; and electro-static (or ion) rocket engines in which the working fluid is heated insignificantly or not heated at all, but is first ionized by some means, after which the flow of ions is accelerated in an electrostatic field.

Electric rocket engines are of limited power because of the need to have an electric generator, so their thrust is usually very small, it is so far measured in grammes and will be increased probably to kg. Therefore electric rocket engines can be used only in space, after the vehicle has already attained the first cosmic velocity. A space vehicle must be launched by powerful rocket engines with a thrust greater than the rocket's weight. The engines used can be solid-propellant, liquid-propellant, or nuclear-powered. On the other hand, when an electric rocket engine is started, even with its small thrust, it can accelerate the space vehicle to a very high speed if it works for a long period of time. Length of operation is frequently many months at a time. Herein lies one of the fundamental differences of the electric rocket engine from the rapidly burning out chemical rocket engines. Propellant consumption, despite such a slow acceleration of the spacecraft, proves to be considerably smaller, this resulting from the considerably greater specific impulse of electric rocket engines. The payload, therefore, can be correspondingly increased. Electric rocket engines are likely to be used for long and complicated space flights, supply transportation, etc. Meanwhile, they are already being used in the ORIENTATION systems of space vehicles. The first experimental electric rocket engine (of the electrothermal type) was developed by the GDL in 1929—1933. In recent years electric engines were used on space rockets launched both by the USSR and the USA.

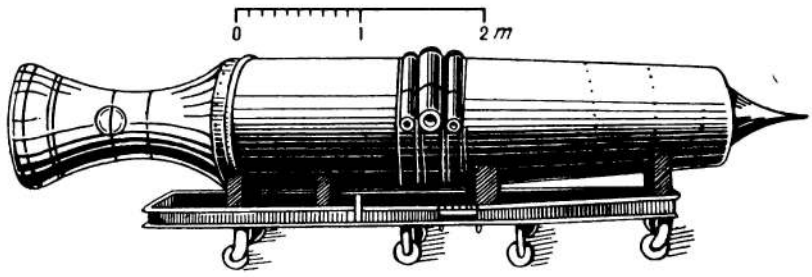
The hypothetical photon, or quantum, rocket engine is the theoretical limit of rocket engines, because the exhaust velocity of the working fluid from a photon rocket engine is the maximum possible velocity in nature, speed of light, and flowing out of the photon rocket engine are not molecules or atoms but photons, light quanta. A photon rocket engine would be the most suitable one for especially complicated and long space flights, such as inter-



Rocket-handling dolly (USA).



(*a*)



(*b*)

Rocket ramjet engine: (*a*) schematic diagram; (*b*) general view.
1—rocket engine; *2*—engine body; *3*—propellant injectors.

planetary travels, but contemporary science is yet to find ways of creating such engines.

ROCKET-HANDLING DOLLY. A wheeled trailer intended for transportation of launch vehicles or individual stages thereof over hard-surface roads and improved earth roads. Its basic components are: frame, cradles, supports and grabs for fastening the launch vehicle or a stage thereof, controlled front and rear wheel axles with brakes to increase steering manoeuverability, a parking brake and a shock-absorbed tow pole. The dolly is 30 to 60 m long. The dollies for transportation of heavy-weight stages of solid rockets have wheel hubs with built-in electric or hydraulic motors.

ROCKET PROPULSION SYSTEM. The powerplant of an aircraft, spacecraft, or rocket, comprising the rocket engine (or engines) with its mount, and, sometimes, propellant tanks and automatic devices. The system may include 1, 2, 3 or more engines.

ROCKET-RAMJET ENGINE. A combination rocket engine, an integration of rocket and ramjet engines. It is under development for aerospace planes.

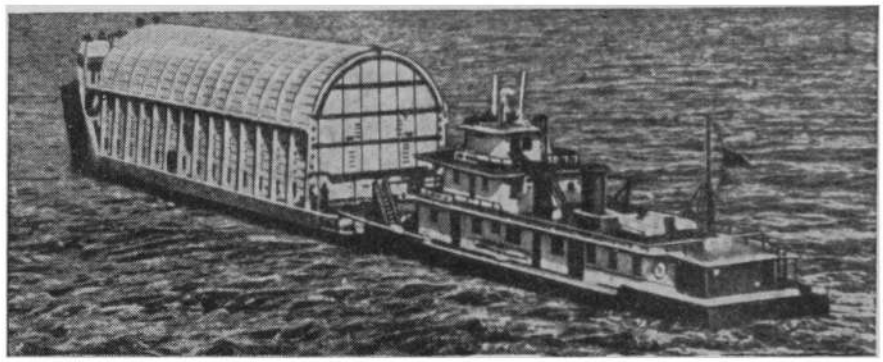
ROCKET RESEARCH INSTITUTE (RNII). A research and development organization founded in Moscow in September, 1933, around the core of the Gas Dynamics Laboratory (GDL) and the Group for Study of Reactive Motion (GIRD). The chief of the GDL, I. T. Kleimenov, was appointed chief of the RNII. The chief of GIRD, S. P. Korolev, was appointed his deputy. From January, 1934, G. E. Langemak, deputy-chief of GDL, became deputy-chief of the RNII. The staff of the Institute maintained close contact with K. E. Tsiolkovsky. The range of subjects dealt with at the Institute covered all the basic problems of rocket engineering. From this Institute came a number of experimental ballistic and winged rockets and engines for them. Between 1934 and 1938 a large number of rockets were launched. In 1939 winged rocket *212* with an *OPM-65* engine was put through flying tests and in 1937—1938 a rocket glider *РП-318* with an *OPM-65* engine was ground-tested. In 1940, the pilot V. P. Fyodorov was the first to fly an *РП-318* powered by an engine which was a modification of *OPM-65*. In 1942, the pilot G. Y. Bakhchivadzhi made a flight on a *БИ-1* rocket plane powered with a *Д-1-А-1100* liquid-propellant engine.

In recognition of the fundamental contribution of the Rocket Research Institute to the development of Soviet rocketry, a 540-km long chain of craters on the reverse side of the Moon has been named after this organization.

ROCKET SHIPPING BARGE. A facility for shipping individual stages of huge launch vehicles. Provision is made on the barge deck for fastening the launch vehicle in a stowed position. The deck also mounts hangars for protecting the launch vehicles against the effects of adverse environments. Launch vehicles are loaded on the barge by means of cranes or with the use of missile-handling dollies. The barges can be either self-propelled or tugged. They are up to 100 m long and over 20 m wide. See Fig., p. 360

ROCKET SITE. See Space centre.

ROCKET STAGE. A sub-assembly of a multi-stage rocket serving to propel it over a certain portion of the powered-flight phase and generally consisting of a propellant compartment containing the fuel and oxidizer, rocket



A tugged barge with a hangar for shipping individual stages of a missile (USA).

engines, propellant supply system, actuators, control instrumentation, structural elements, and mechanical equipment (system for stage separation, tail or stage adapter, etc.).

As soon as the given stage consumes its propellant (burns out) and ceases operation, it is separated from the remaining stages of the rocket as the latter continues its flight. The last stage of a rocket carries the PAYLOAD.

ROCKET STORAGE FACILITY. The premises for long-term storage of space vehicles or their stages, sub-assemblies and elements packed for storage on dollies or supports. The temperature and humidity of the store-room air is maintained at a specified level.

ROCKET SYSTEM SIMULATOR. A set of equipment and instruments including space-borne control systems of the launch vehicle, used for testing the check-out and launching equipment of a launch complex and the stand-by instruments on board the vehicle. The simulator equipment is usually mounted on a truck or in the launcher.

ROTATING ROOM. A stand for studying the effect of sustained low-level accelerations on man's organism; the purpose is professional selection and VESTIBULAR TRAINING.

ROY, Louis Maurice (born 1899). French scientist, member of Paris Academy of Sciences since 1949 and its President since 1966. Graduated from Ecole Polytechnique, Paris. Worked for defence agencies (1922). Professor at Ecole Nationale des Ponts et Chaussées (1926—46); Professor at Ecole Nationale Supérieure de l'Aéronautique (1930—40); Professor at Ecole Polytechnique (1947); Director, Office National d'Etudes et de Recherches Aéronautiques (1949—62). Author of prominent works in mechanics and thermodynamics. President of Committee on Space Research (COSPAR).

РП-318 (*RP-318*). The first Soviet rocket glider, an aircraft using a liquid-propellant engine. Designed by S. P. Korolev and developed in 1939—40 by RNII. *РП-318* was a midwing monoplane with high-aspect-ratio wings; the propellant tanks were inside the fuselage behind the cockpit, the engine being accommodated under the tail unit of the glider. The take-off weight equaled 657 kg, the propellant weight (nitric acid and kerosene) was 75 kg; the glider length was 7.9 m, the wing span, 17 m; the design speed was

270 km/h. Ground tests were initially carried out in 1936—38 with an *OPM-65* rocket engine, subsequent ground and flight tests with *РДА-1-150* engine (lower-performance version of *OPM-65*; 70—140 kg of thrust *vs.* 50—175 kg; 186 s of specific impulse at 140 kg of thrust *vs.* 210 s at 150 kg). The maiden flight of the *РП-318* glider with the engine operating was performed by pilot V. P. Fyodorov on February 28, 1940. The flights of the *РП-318* glider furnished valuable data for further development of jet aircraft.

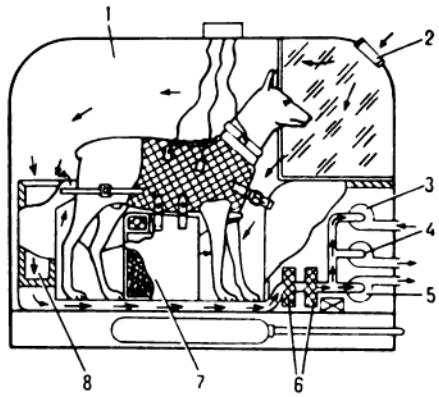
RYNIN, Nikolai Alexeyevich (1877—1942). Soviet scientist in the field of aviation and descriptive geometry, the author of a number of works on reaction craft, interplanetary travel, and conquest of the stratosphere. In 1901 graduated from the St. Petersburg Institute of Transportation Engineering, and in 1920 organized a Department of Air Communications there. Beginning with 1921 was a professor at that department. Rynin made experimental studies of the effects of inertial forces on the live organism. In 1918 his conclusion on the N. I. KIBALCHICH's project of a reaction aircraft was published. Rynin is the author of a monograph entitled *Teoria aviatsii* (*The Theory of Aviation*, 1917), a handbook on *Proyektirovaniye vozdushnykh soobshcheniy* (*Designing Air Communication*, 1937), etc. His work *Mezhplanetnyie soobshcheniya* (*Interplanetary Communications*), published in 1928—32, was the first encyclopedia of the history and theory of reactive motion and space flight. It consists of 9 books: Vol. 1, book 1—*Dreams, Legends, and Early Fantasies*; Vol. 1, book 2—*Spaceships as Imagined by Fiction Writers*; Vol. 1, book 3—*Radiant Energy in the Fantasies of Fiction Writers and Projects of Scientists*; Vol. 2, book 4—*Rockets and Engines of Direct Reaction*; Vol. 2, book 5—*Theory of Reactive Motion*; Vol. 2, book 6—*Superaviation and Superartillery*; Vol. 3, book 7—*Biography of K. E. Tsiolkovsky, Russian Inventor and Scientist. His Work and Rockets*; Vol. 3, book 8—*Theory of Space Flight*; Vol. 3, book 9—*Astronavigation. Chronicle and Bibliography.* Rynin was the organizer and president of the INTERPLANETARY TRAVEL STUDY GROUP, set up in 1928 at the Leningrad Institute of Transportation Engineering. Beginning with 1931 he collaborated with LenGIRD. A crater on the far side of the Moon bears his name.

S

SAMPLING UNIT. A device for taking propellant samples from a propellant tank or terminal. The samples of several litres each are taken periodically for analysis of the chemical composition, concentration, content of mechanical and chemical impurities. The sampling unit consists of a removable tank accommodating a sample, pipe-lines and shut-off valves.

SÄNGER, Eugen (1905-64). German scientist. Studied at Graz and Vienna Institutes of Technology (1923—29); assistant at Vienna Institute of Technology (1930—35); engaged in study of rocketry (since 1936) including liquid-propellant engines, rocket-propelled aircraft, etc. Author of *Raketen-Flugtechnik* (*Rocket Flight Technique*, 1933), *Zur Mechanik der Photonen-Strahlantriebe* (*Concerning the Mechanics of Photon Power Plants*, 1956). President of the International Astronautical Federation (1950—52), head of the Deutsche Gesellschaft für Raketentechnik und Raumfahrt, Stuttgart (since 1956).

SANITATION UNIT. A unit for receiving biological wastes of man and other living organisms and transporting them to the system for regeneration of water and mineralization of solid wastes (or, in a particular case, to isolated preservative-containing vessels). The sanitation unit also includes devices for meeting personal hygienic requirements of the crew and for improving the sanitary and hygienic state of the sealed cabin. Depending on the flight duration, the sanitation unit may include hygienic napkins, wash-stands, showers, vacuum cleaners, collectors of food wastes and spent means of personal hygiene, etc. The illustration shows a sanitation unit operating on the principle of forced suction of the animal's wastes by air which brings the solid wastes into an appropriate collector and, after passing the collector, is filtered.

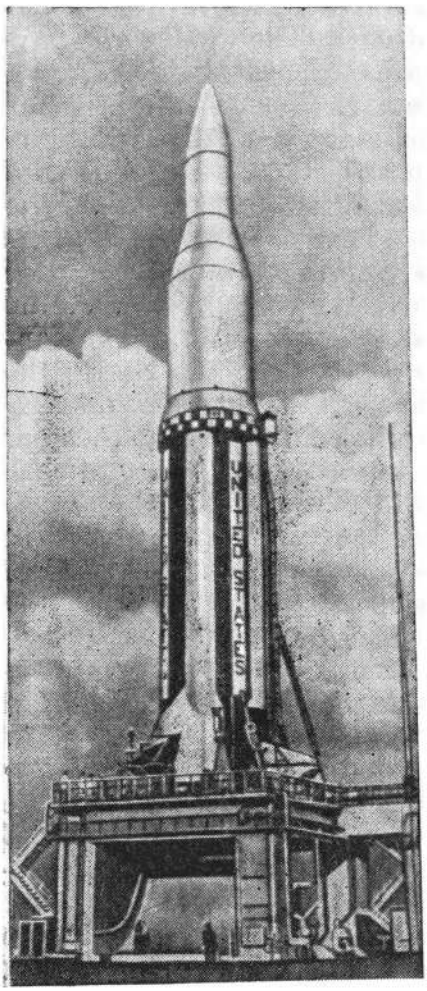


Sanitation unit in *Cosmos-110* cabin.
1—sealed container with animal; *2*—inlet for conditioned air; *3*—fan; *4*—redundancy fan; *5*—additional high-power fan; *6*—filters; *7*—liquid-waste collector; *8*—solid-waste collector

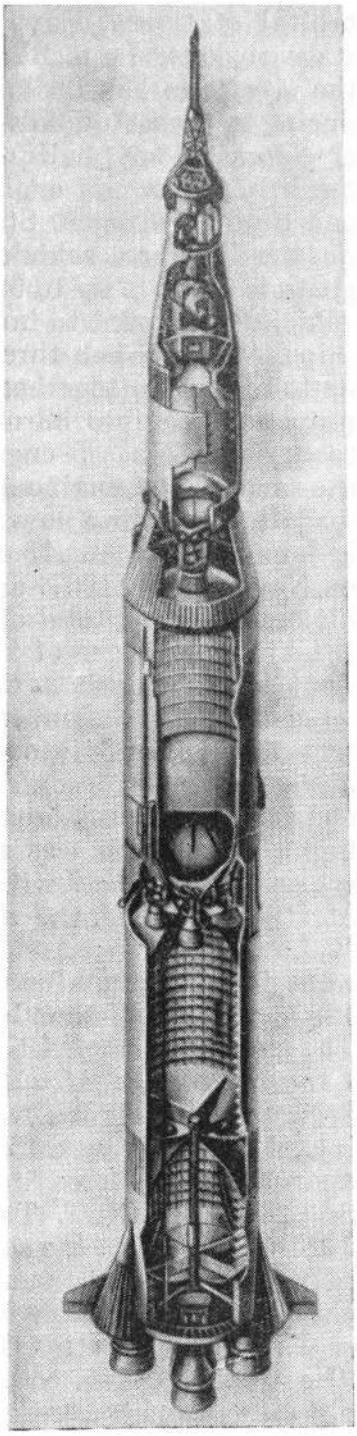
SAPROPHYTES. Living organisms obtaining nourishment through cell membranes, by absorbing organic materials from the products of decaying plants or animals. Yeasts, fungi and most bacteria are typical saprophytes. They are included in the spaceship biocomplex for mineralization of biological wastes (bacteria) and partial reproduction of food (yeasts and certain species of fungi).

SATELLITES OF PLANETS, natural. The celestial bodies that revolve about the planets of the SOLAR SYSTEM. There are 31 known natural planetary satellites. See also MOON.

SATURATION OF PROPELLANT WITH NITROGEN. Dissolution of nitrogen in propellant to the degree of complete saturation, achieved usually by bubbling. It is used when there is a threat of the pressurization nitrogen being absorbed by the propellant in the launch vehicle tank, thus interfering with the process of pressurization during the operation of the rocket powerplant.



Saturn-1.



Saturn-5.

SATURN LAUNCH VEHICLE. The name of a series of powerful American launch vehicles intended to develop and launch APOLLO spaceships, manned

orbital stations, heavy satellites, etc. *Saturn-1* and *Saturn-1B* are two-stage rockets. Launching weight is 520—580 t, total length together with the *Apollo* is 58—68 m, stage 1 has 8 liquid-propellant engines each producing a thrust of 85—90 t, using LOX-and-kerosene propellant. Stage 2 of *Saturn-1* has 6 liquid-propellant engines with a thrust of 6.8 t each. *Saturn-1B* has one engine that develops a thrust of 90.7 t by firing LOX and liquid hydrogen. Stage 2 of the *Saturn-1B* is employed as stage 3 of the *Saturn-5* launch vehicle. The weight of the payload injected into a low-altitude orbit is up to 9 t for *Saturn-1*, and up to 15 t for *Saturn-1B*. These vehicles were used to launch the *Pegasus* satellites and dummy *Apollo* spaceships. *Saturn-5* is a three-stage vehicle with a launching weight of ~2750 t, its total length (together with *Apollo* spaceship)is 107 m. Stage 1 has 5 liquid-propellant engines burning LOX and kerosene to produce a thrust of 680 t each; stage 2 has 5 engines with a thrust of 90.7 t each, while stage 3 has the same rocket engine using LOX and liquid hydrogen. The weight of a payload it places in a low orbit is ~130 t. The main purpose of the *Saturn-5* is launching of an *Apollo* spaceship to the Moon. In the first flight made on November 9, 1967, an unmanned *Apollo-4* and stage 3 of the launch vehicle, weighing a total of ~127 t, were injected in an orbit with a perigee of 184 km and apogee of 190 km; after repeated starting of stage 3, the *Apollo* went into an orbit with an apogee of 17,700 km and continued its flight on a special mission. On January 22, 1968, a *Saturn-1B* launch vehicle sent the *Apollo-5* into circumterrestrial orbit to make a flight test of the *Lunar Excursion Module* of the *Apollo*. On April 4, 1968, *Apollo-6*, an unmanned spaceship, was launched by a *Saturn-5* into orbit round the Earth; the flight programme was not completed. On October 11, 1968, a *Saturn-1B* orbited the *Apollo-7* with a crew of 3. A *Saturn-5* was employed on December 21, 1968, to send the *Apollo-8* into space with the astronauts F. Borman, J. Lovell and W. Anders on board; the spaceship flew towards the Moon, went into a circumlunar orbit and then returned to the Earth. March 3, 1969, witnessed the launching of the *Apollo-9* by a *Saturn-5* vehicle. The spaceship carried three astronauts. The mission was flight testing of the *Lunar Excursion Module*. The total weight injected into orbit (spaceship, 3rd stage of launch vehicle with propellant residues, and spaceship-to-rocket adapter) was 135 tons. The orbit had a perigee of 190 km and an apogee of 191 km.

SATURN, PLANET. The second largest (in size and mass inferior only to Jupiter) planet in the solar system and the 6th in the order of distance to the Sun. The mean distance to Sun is 9.539 AU (1427 million km), the orbital eccentricity is 0.0556, inclination of orbital plane to ecliptic 2° 29.4′, sidereal revolution period 29.458 years, and a mean orbital velocity 9.6 km/s. The albedo is 0.76, colour bright yellow. The surface of Saturn is invisible, an estimation has been made of the physical characteristics of the figure formed by non-transparent layers of the atmosphere; a mean dia of 116,820 km comprises 9.17 (Earth = 1), the compression 1 : 10, the mass is $5.7 \cdot 10^{29}$ g or 95.1 (Earth = 1), the mean density is about 0.68 g/cm^3. The mean gravity (minus the centrifugal force which amounts to 1.76 m/s^2) is 9.06 m/s^2 (0.93 of the Earth's), the 2nd cosmic (parabolic) velocity is 33 km/s. The atmo-

spheric depth, radius and the character of solid surface of Saturn are unknown. The rotation period about the axis performed by the atmospheric zone is 10 h 14 min, that of polar zones is 26 min slower. The equatorial plane is inclined 26° 44′ to the orbital plane. The most remarkable feature of Saturn is its unique system of rings lying in the equatorial plane: the outer ring *A* (with radii of 139—120 thou. km), separated from the inner ring *B* (with radii 117—89 thou. km) by the so-called dark Cassini division, and the crape *C* ring (with radii of 89—72 thou. km). The ring system is made up of separate meteoric bodies about 1 m in size, the estimated thickness of rings is between 5 and 0.3 km. The visible disk of Saturn is crossed by two belts restricting its tropical zone. The temperature of the outer layer of Saturn in the sub-solar point is 95°K. The composition of atmosphere is much like that of Jupiter, but more of ammonia is condensed. Saturn has 10 known satellites. The largest, Titan, has a dia of 5 thou. km. Its atmosphere consists of methane. The 2nd cosmic velocity there is 2.8 km/s.

SCALE HEIGHT (height of homogeneous atmosphere). Characteristic scale of variation of atmospheric density with height. Over the interval of heights equal to the scale height the isothermal atmosphere pressure in homosphere region declines by a factor of *e*. The scale height is directly proportional to absolute temperature and inversely proportional to average mass of particles and acceleration of gravity. In the upper part of the HETEROSPHERE, the scale height is also characterized by the rate of variation of the concentration of individual atmospheric components with height; in this case the formula for H must include the mass M_i of particles under consideration instead of the average mass M. The scale height of positive single-charge ions of mass M_i in an isothermal ionosphere above the maximum of the *F* layer is twice as large as that of neutral atoms of the same mass and at the same temperature, which is due to an electric field induced in the ionosphere owing to the difference between the masses of ions and electrons.

SCATTERING OF RADIO WAVES. A phenomenon observed to occur irregularly with time in a heterogeneous medium and consisting in propagation of radio waves in directions different from the direction of the emitted wave. Scattering is appreciable in the troposphere for centimetre and decimetre waves, while in the ionosphere it is tangible for short waves and waves longer than these. The tropospheric scattering effect is utilized in ground communication radio relay lines operating on the decimetre waves. Ionospheric scatter is utilized by operating on the metre waves.

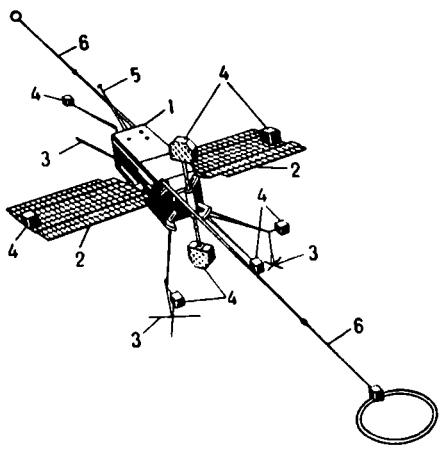
SCHEDULE MAINTENANCE TESTS. A series of operations performed periodically (daily, quarterly, yearly, etc.) during storage and operation of space vehicles and ground support equipment for checking their condition, detecting and eliminating faults. The complexity of schedule maintenance tests depends upon the degree of the rocket system readiness for launch. Checkout and launch equipment is used for conducting these tests.

SCHIRRA, Walter Marty, Jr. (born 1923, in Hackensack, N.J.). A US astronaut, commander in the USNavy. Graduated from the US Naval Academy in 1945 and from the Naval Air Safety Officer School at the University of Southern California in 1957. Later graduated from the Test Pilot School

at the Naval Air Test Centre. Took his pilot's training at the Naval Air Station, Fla., and served in various units of the USAF and USNavy. Joined the group of astronauts of the NASA in 1959. Made his first space flight on October 3, 1962, in the *Mercury* (*Sigma-7*) spaceship. The spaceship made 6 orbits in 9 h covering a distance of 230,000 km. Made his 2nd orbital flight as command pilot of *Gemini-6* (together with T. STAFFORD). The spaceship was put in orbit on December 15, 1965, and was to meet *Gemini-7* launched on December 4. On December 15, *Gemini-6* approached *Gemini-7* as near as ~0.3 m. Their joint flight lasted 3.5 h. *Gemini-6* orbited the Earth 15 times in 26 h. On his 3rd space flight, October 11—22, 1968, Schirra acted as command pilot of *Apollo-7* spaceship with W. CUNNINGHAM and D. EISELE on board. The spaceship revolved around the Earth 163 times in 10 days 20 h 9 min.

SCHWEICKART, Russel L. (born 1935, Neptune, N.J.). US astronaut, former USAF pilot (1956—60). B. Sc. in aeronautical engineering (1956) and M.Sc. in aeronautics and astronautics (1963). Research scientist at the Experimental Astronomy Laboratory of the Massachusetts Institute of Technology. Joined the NASA astronauts in 1963. Made a 10-day space flight (together with J. McDivitt and D. Scott) in the *Apollo-9* launched into geocentric orbit on March 3, 1969. Schweickart performed complex programme of flight testing the *Lunar Excursion Module* systems and spent 37.5 min in open space.

SCIENTIFIC SATELLITE. An artificial Earth satellite intended mainly for carrying out various investigations of the outer space, upper atmosphere, the Earth and other celestial bodies with the aid of space-borne research equipment. The scientific satellites vary in weight, size, design, equipment and instrumentation. More than 400 scientific satellites have been launched before January 1, 1969; their weight ranges from a few kg to ~17 t, the flight altitude varies from 150 to 400,000 km (in apogee). Measurement data from scientific satellites are transmitted to the Earth through radio



OGO-2 research satellite (USA).
1—body with main space-borne systems; *2*—solar batteries; *3*—antennas; *4*—containers with scientific instruments; *5*—rod carrying attitude control nozzles; *6*—6.7-meter long rods for holding out certain sensors.

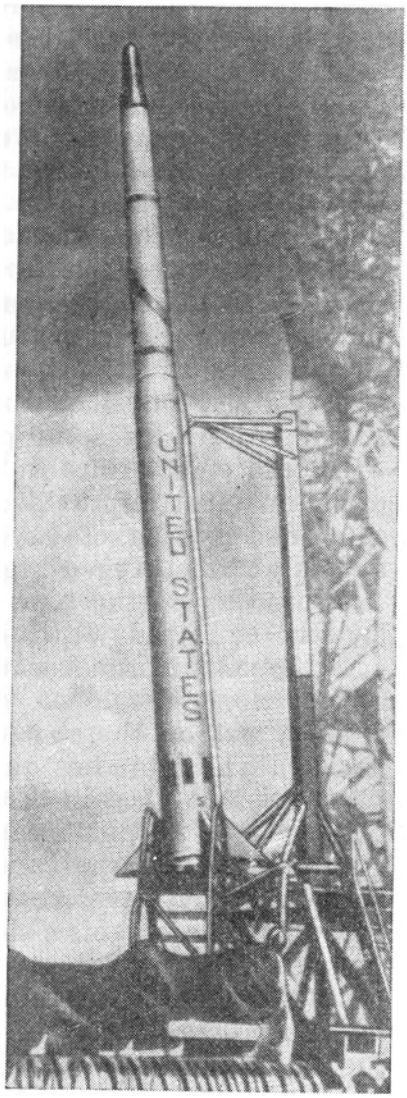
telemetry systems. An alternative method is to land the re-entry body containing scientific equipment and experimental animals (as was done with the *Cosmos-110* satellite). The Soviet satellites of the *Cosmos*, *Electron*, and *Proton* series, the American satellites of the *Explorer*, *OSO*, *OGO*, *OAO* and *Pegasus* series and others are referred to as scientific satellites. Scientific instrumentation can be installed on satellites launched with other purpose.

SCOTT, David R. (born 1932, San-Antonio, Tex.). A US astronaut, USAF officer. Graduated from the US Military Academy and the Massachusetts Institute of Technology with a degree in aeronautics and astronautics. Graduated also from the USAF Experimental Test Pilot School and the USAF Aerospace Research Pilot School. Joined the group of astronauts of the NASA in 1963. Acting as the co-pilot, made an orbital flight together with N. ARMSTRONG in the *Gemini-8* spaceship on March 16, 1966, circling the Earth 7 times in 10 h 40 min. It was at this flight that *Gemini* was coupled in orbit with an *Agena* target rocket for the first time. Unforseen oscillations of the spaceship and the rocket began within 20 min after the docking was completed. That made it necessary to disconnect the spaceship from the rocket and to land it ahead of schedule. Scott was a crew member (together with J. McDivitt and R. Schweickart) in the 10-day space flight of the *Apollo-9* launched on March 3, 1969. The spaceship made 151 orbits round the Earth covering a distance of 6,300,000 km. The crew performed a complex programme of varied investigations, including flight testing of the *Lunar Excursion Module.*

SCOUT. A series of American launch vehicles which have been used since 1960 for placing small satellites into orbit. *Scout* is a four-stage rocket with solid-propellant engines in all stages. The launching weight is about 17 t, total length 22 m, the thrust developed by the 1st stage is 52 t. The payload placed into a low orbit is 70—140 kg depending on the rocket version. *Scout* rockets were used for launching a number of small satellites: *Explorer*, *Secor*, *Transit*, French satellite *FR-1*, etc.

SCREEN-VACUUM HEAT INSULATION. The external heat insulation provided around space vehicles or their compartments, such as cryogenic tanks. It consists of a series of thin shields with vacuum between them. Practically, this is a large number of layers of thin metallized film with a porous separator, e.g., glass cloth, between them. In flight, vacuum is built up in the porous layers (see TEMPERATURE CONTROL SYSTEM).

SEALED CABIN. A sealed compartment in a spaceship accomodating the crew and all the



Scout American launch vehicle.

Sealed cabin

controls. The sealed cabin isolates the spacemen from space vacuum and protects then against solar and galactic radiation, meteoric particles and heat flows. The cabin should provide the environment necessary to maintain the life functions of the human organism for the period of time stipulated by the space flight programme. The LIFE SUPPORT SYSTEM provides an artificial atmosphere and the required food and water, disposes of wastes, and maintains customary sanitary conditions in the cabin.

The spaceman's capacity for work is preserved during prolonged space flights by providing the sealed cabin with a gas medium whose physical and hygienic parameters are the same as those of the Earth's atmosphere. The cabins of Soviet spaceships contain a normal mixture of oxygen and nitrogen with a pressure of about 750—770 mm Hg, a relative humidity of 45—60% and a temperature of 18°—21°C. In all American spaceships (including *Apollo*) pure oxygen at a pressure of 285—360 mm Hg is used. An atmosphere of oxygen makes it possible to reduce the weight of the sealed cabin, since the walls have to withstand a smaller pressure differential in space. However, in flights lasting over 30 days, pure oxygen at this pressure has a toxic effect; besides, in such an atmosphere, even small sparks cause instantaneous inflammation of combustible materials, and the flame spreads rapidly. This may lead to a fire inside the sealed cabin, especially in the pre-launch period, when the absolute pressure of oxygen is increased (see CABIN ATMOSPHERE).

The cabin atmosphere must be continuously cleansed of physiological wastes, such as carbon dioxide, exhaled moisture, intestinal gases, excretions of the skin, and contamination by suspended solid particles, micro-organisms and micro-admixtures generated by cabin equipment, lubricants, plastics, etc. The atmosphere regeneration systems can include biological cultivators, space farms, physical and chemical absorbents for carbon dioxide and odours, filters for solid particles, and condensers for excess moisture.

In case of a failure in the regeneration system or cabin sealing, special pressure suits are provided. The suit worn by each crew member has a self-contained system of oxygen supply from space-borne oxygen containers and means for oxygen regeneration.

Depending on the type of the emergency escape system, the sealed cabin may be equipped with ejection (*Vostok* and *Gemini*) or ordinary (*Voskhod* and *Mercury*) contour seats. The seats are installed in such a way, that the accelerations developed during the spaceship's injection into orbit and re-entry act on the spaceman in the "chest-to-back" direction (see ACCELERATION). The cabin has quick-release hatches and observation windows with heat-resistant glass in the front and side walls. These windows permit visual observation and photographing. If the cabin is filled with an oxygen-nitrogen mixture at a pressure approximating normal atmospheric pressure, the spaceman may leave the cabin for open space only through an air lock chamber where his organism desaturates the dissolved nitrogen and the ambient pressure gradually decreases to about 180—257 mm Hg, which is equal to the oxygen pressure in the space-suit (see DECOMPRESSION SICKNESS). All equipment within the sealed cabin must be arranged so as to meet the requirements of industrial design and to constitute an optimum interior. The

sealed cabin may comprise a number of compartments, e.g., the ones to accommodate the crew, the instruments, the LSS, etc.

The outer surface of the sealed cabin is covered with a heat-protective ablation layer, which prevents burning of the sealed cabin during re-entry. The air in the cabin is maintained at the comfort temperature of 15°—22°C by the temperature control system. In addition to navigation equipment and manual controls, the cabin contains radio equipment for two-way communication with the ground stations, TV cameras, in particular, for observation of the crew, instrumentation that records physiological functions of the spacemen during flight, and many other devices. When making tests to study the effect of ENVIRONMENTAL FACTORS of space flight on the human organism or the spacemen's working capacity during extended flights, the conditions of the crew in the sealed cabin must be simulated as precisely as possible (see SIMULATION).

SEARCH OF REFERENCE POINTS. One of the initial stages of spacecraft orientation during which the REFERENCE POINTS are captured automatically by position pick-offs of orientation or the spaceman's sighting device. The method of search actually employed depends upon the type of reference points that have been adopted for orientation. The most simple search is that of the Sun or a nearby planet (e.g., of the Earth from a low-orbit satellite); such a planet differs from other celestial bodies in its considerable angular dimensions and in that it occupies a greater part of the sphere of view. Search of bright stars is based on the fact that they are not too numerous (there are only twenty stars of the first magnitude) and that their relative distribution in the sky and positions with respect to the Sun are well known for any given moment of time. The search of faint stars is more difficult as their great number and close disposition causes a sharp increase in error probability. Such a problem or orientation is most effectively solved by the spaceman (see MANUAL CONTROL).

SECOND. Unit of time. The official definition of 1 mean solar second is 1 : 31,556,925.974,7 of the tropical YEAR for 1900, January 0 at 12 h. The sidereal second is the 86,400th part of the sidereal day (see TIME).

SECOND COSMIC VELOCITY. The minimum initial velocity which, if imparted to a body near the surface of the Earth, enables this body to escape from the Earth's gravitational pull. It depends on the height above the surface; at the surface of the Earth it is equal to 11.19 km/s. If, at the initial moment, the body moves at the 2nd cosmic velocity and is influenced by no other force except the Earth's gravity, it will travel over a parabolic trajectory in respect to the Earth.

SECULAR DISTURBANCES. Disturbances proportional to time t (or t^k, where k is a positive integer). Secular disturbances increase infinitely with time. This is why they play an important part in the evolution of the orbits of celestial bodies. Effective methods for determining secular disturbances have been worked out by Gauss and Lagrange.

SECULAR-PERIODIC DISTURBANCES. Disturbances that can be expressed in the form of a product of time t (or t^k where k is a positive integer) multiplied by a periodical function of time. They can be considered as periodic disturbances with an amplitude infinitely increasing with time.

SEDOV, Leonid Ivanovich (born 1907). Soviet scientist (mechanics). Academician since 1953. After graduation in 1931 from Moscow University, worked at the Central Aero-Hydrodynamics Institute and, since 1947, at the Institute of Aeroengine Design. Professor at Moscow University since 1937. In 1954—62, Chairman of the Standing Interdepartmental Commission for Coordination and Control of Scientific and Theoretical Work in the Field of Organization and Implementation of Interplanetary Travel under the Astronomical Council of the Academy of Sciences of the USSR. President of International Astronautical Federation (1959) and Vice-President of same (1963), member of International Academy of Astronautics (1960). Was awarded the Oberth Medal by the German Interplanetary Travel Society in 1960.

SELECTION OF SPACEMEN. Choosing, from among volunteers, of persons capable of enduring the conditions of a given space flight, preserving adequate working capacity, fulfilling the flight mission, and returning safely to Earth. The selection of spacemen involves forecasting of the spaceman's tolerance to the conditions of a given space flight, this forecast being based on an analysis of the flight conditions, evaluation of the spaceman's health status and his functional possibilities. A comparison of the data obtained during selection with those obtained in the space flight proper and post-flight examination makes it possible to evaluate the accuracy of the forecasting, and serves as a basis for the development and specification of the programme for selecting and training spacemen for future space flights.

SELENOLOGY. The branch of PLANETOLOGY which studies the lithosphere of the Moon. The aim of modern selenology is to study the structure and origin of craters, composition of rocks and evaluation of their mechanical strength, the evolution of lunar lithosphere, etc.

SELF-CONTAINED RECORDING SYSTEM. A space-borne system that makes magnetic tape records of the data obtained by measuring the flight characteristics and the performance of the spacecraft systems. It is usually installed in the re-entry body for recording flight data during re-entry. It complements the telemetry system in obtaining data on the re-entry phase during which telemetry is rendered difficult or impossible due to ionization of the air through which the re-entry body travels.

SELF-CONTAINED SYSTEM of navigation. A system that fulfills the assigned navigational task by the sole agency of space-borne equipment or the crew on board. A self-contained system does not need any links with ground command, telemetry or computer stations.

SELF-EXCITED VIBRATION in rocket engine. The oscillations whose steady-state frequency and amplitude are dependent solely on the properties of the vibratory system referred to as a SELF-EXCITED VIBRATORY SYSTEM. In such a system a source of energy makes up for the losses, therefore self-excited vibration can exist without any periodical external influence. This

distinguishes the self-excited vibration from the FORCED VIBRATION. There are low-frequency and high-frequency self-excited vibrations of gas pressure in the thrust chambers and gas generators of rocket engines. Characteristic for the low-frequency self-excited vibration is the equal gas pressure at all the points inside the thrust chamber or gas generator at any given moment of time. The low-frequency vibration depends on the liquid-propellant feed system and is due to the fact that certain period of time is required for the propellant to convert into combustion products. The low-frequency vibration developed in a liquid-propellant engine can be eliminated by changing either the dynamic characteristics of the propellant feed system or the time of conversion, which can be done either by modifying the process of PROPELLANT MIXING or by using more actively interacting propellants. The HF self-excited vibration is characterized by the oscillatory properties of the gas volume in the thrust chamber and the processes inside the thrust chamber, *viz.*, propellant mixing (propellant atomization, mixing, and evaporation), fuel combustion, etc. The frequency of the HF vibration of gas pressure in thrust chambers is determined by the acoustic frequencies of the gas volume. There are longitudinal and lateral (radial and tangential) types of vibration. The combustion of a rocket propellant in the presence of HF self-excited vibration is termed "vibratory". The nature of vibration of pressure and other characteristics of gas are extremely complicated and have not yet been sufficiently investigated. The measures taken to suppress a developed HF self-excited vibration in rocket engines are largely empirical. A highly developed low- and/or high-frequency self-excited vibration may bring about an ultimate destruction of the thrust chamber, the gas generator or other units of the rocket engine due to the engine vibration, burn-through of the inner walls caused by an intensification of heat supply, etc.

SELF-EXCITED VIBRATORY SYSTEM consists of three basic elements, *viz.*, the vibratory system proper (a system capable of periodically changing its characteristics under the influence of external disturbances), a source of energy making up for the losses in the self-excited vibratory system, and a mechanism controlling the delivery of this energy from the source to the vibratory system.

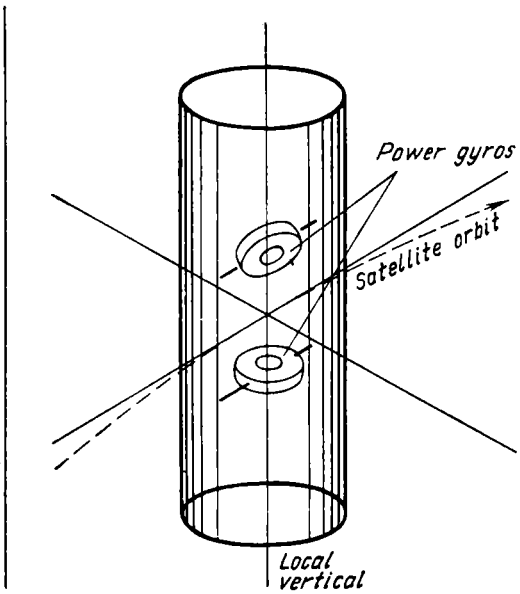
SELF-IGNITING (HYPERBOLIC) PROPELLANT. A two-component liquid propellant (bipropellant) that ignites spontaneously on contact of its components (the oxidizer and the fuel). The use of such propellants makes it possible to simplify the design of rocket engines and to increase their reliability, because there is no need for an ignition system; starting becomes easier, combustion stability is improved, but the operational requirements for sealing are higher.

SEMI-MAJOR AXIS of elliptical orbit. The quantity equal to one half of the major axis of the ellipse that defines the geometrical dimensions of the orbit.

SEMI-PASSIVE SYSTEM OF ORIENTATION. A system of orientation making combined use of operational principles of both passive and active systems of orientation, e.g., a gravitational-gyroscopic system of satellite orientation, in which the GRAVITATIONAL MOMENT orients one of the satellite's axes with respect to the local terrestrial vertical, whereas the other

Sensing elements

2 axes are oriented by one or several power gyroscopes. Owing to the utilization of the gravitational moment, such a system is more simple and economical than an active system of orientation used for the same purpose; on the other hand, the employment of active system elements (gyroscopes) makes it easier to overcome certain difficulties arising in the case of a purely passive gravitational system, such as the problem of efficient damping of the angular oscillations of the satellite.



SENSING ELEMENTS of a control system. Devices used for detecting deviations of the parameters of spacecraft motion from the preselected values and for sending respective signals to the converting units of the flight-control system. In the system that controls the motion of the centre of mass, the sensing elements establish the position, velocity, and acceleration of the spacecraft; in the systems of orientation and angular stabilization, they control the angular coordinates and angular velocity of the spacecraft.

SENSORY DEPRIVATION. Diminition of the flow of afferent impulses to the central nervous system. The deprivation of visual, acoustic and other sensations may cause various functional disturbances in the organism, and, primarily, it may lower the general physiological tone. In space flight the level of outside afferentation (acoustic, visual and olfactory sensations) is, as a rule, lower due to isolation and monotonous conditions. At the same time, the flow of inner, so-called proprioceptive, afferentation (from the musculoskeletal system, the muscles and ligaments) also drops sharply because of weightlessness and motion restrictions. The effects of sensory deprivation on man's state are being studied and used in the selection and training of spacemen in ISOLATION CHAMBERS where certain space flight conditions can be simulated.

SEPARATION SYSTEM. A means serving to divorce a burnout stage from the rocket during flight. The system accomplishes this mechanically by developing forces at the interstage connections, that are sufficient to break the connections and propel the separated stage away from the remaining portion of the rocket. Care must be taken to prevent both parts from striking each other. In separation systems, use is made of mechanical locks or explosive devices (explosive locks, explosive bolts, auxiliary solid-propellant engines, and spring or air-powered pushers). Separation may be effected prior to firing of the next stage or after firing it. In the latter case the force of the jet efflux serves to augment the forces of separation.

SERVICE LIFE of rocket engine. The full operational time of a rocket engine

on a rocket (operational life). The actual life of a liquid-propellant engine is equal to the operational life plus the time of hold-down test firings, usually preceding the delivery of the engine, plus the reserve required to ensure reliable operation during service. The engines of the upper stages of rockets have the longest service life. The life of solid-propellant engines reaches tens and hundreds of s, that of liquid-propellant ones, several min and h, that of electrical rocket engines, thousands and tens of thousands of h.

SERVICE PLATFORMS. Horizontal supporting platforms with railings, located during the pre-launch preparation of the space vehicle at each level of servicing. They are intended for the accommodation of instruments, machinery and operators engaged in preparing the vehicle for launching. The service platforms are components of service units, erectors and launchers. They can be stationary or mobile, being extended to the working position either horizontally or vertically. The service platforms ensure all-round access to all the vehicle hatches at a given service level, or only to the hatches located in a limited sector. Sometimes the service platforms are completely isolated from the environment and supplied with conditioned air. The number of service levels may attain 15. The upper platforms can be situated at a height of over 100 m.

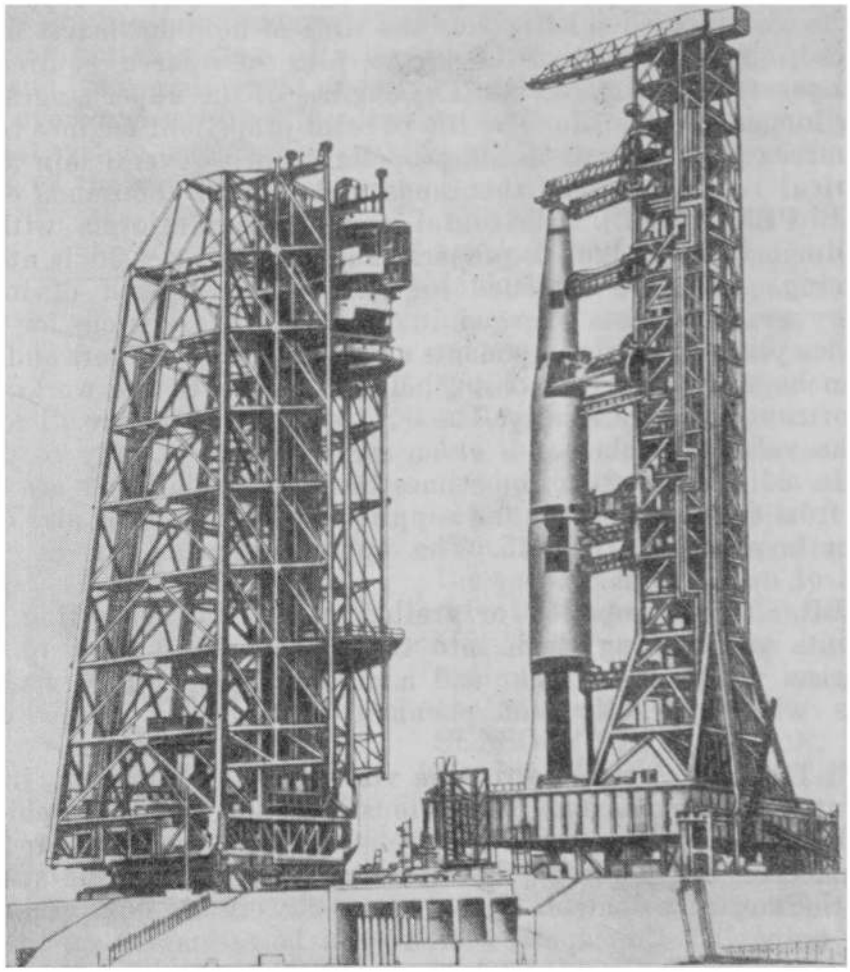
SERVICER. A self-propelled or trailed unit for transporting propellant components and loading them into the space vehicle prior to launching. It comprises a chassis, a tank, and a pumping plant. The servicer carries pipelines with hydraulic and pneumatic fittings, a pump drive, and gauges.

SERVICE TOWER. A metal structure via which the personnel, instruments, equipment, etc., are conveyed to various levels of the space vehicle erected on the launch pad. The service tower often incorporates pipelines with filler connectors for loading propellant components into the space vehicle and for thermostatic control. Some service towers are equipped with high-capacity cranes, so that space vehicles can be assembled on the launcher. The platforms on the service towers are reached by lifts and stairs. Prior to launching the space vehicle, the service tower is moved to a safe distance from the launcher (being hauled by a transporter or, if self-propelled, moving along tracks). Advanced service towers are over 100 m in height and ~50 m wide at the base, they weigh up to 3500 t. Some service towers are self-contained units equipped with power stations, heating, air conditioning, lighting, ventilating, and communication systems. See Fig., p. 374.

SERVICE TRUSS. A structure on the launching site used similarly to the SERVICE TOWER, but not for vertical assembly.

SERVO MOTOR. An electromechanical or any other type of power drive used in spacecraft angular stabilization system to control the position of vernier engines, jet vanes, or gimbaled sustainer engine.

SEXTANT, space. An optical navigational instrument used by spacemen to determine the angular distance between celestial REFERENCE POINTS or their elevation above the local horizon (after landing on a planet). The difference between this sextant and marine sextants is that the former can make measurements from the cabin of the spaceship and can be used while wearing a spacesuit.



Retraction of the service tower prior to launching a rocket (USA).

SHATALOV, Vladimir Aleksandrovich (born 1927, in Petropavlovsk, North Kazakhstan Region). Pilot-Cosmonaut of the USSR. Colonel. Hero of the Soviet Union. Member of the CPSU since 1953. Graduated from an Air Force special school, an elementary school for pilots, and the Kachinsk Air Force Pilot School. Was an instructor pilot. Graduated from the Air Force Academy, now known as the Gagarin Academy, in 1956. Served with the Soviet Air Force. Was enlisted in the group of cosmonauts in 1963. On January 14—17, 1969, made a space flight as commanding officer of the *Soyuz-4*. During this flight Shatalov performed the manually-controlled approach and docking of the *Soyuz-4* and the *Soyuz-5* piloted by B. V. Volynov. This was the world's first experimental space station assembly; it permitted cosmonauts A. S. Yeliseyev and Ye. V. Khrunov to pass through open space into the *Soyuz-4*, in which they returned to the Earth. Shatalov spent 71 h 14 min in space; he orbited the Earth 48 times, covering 1,950,000 km.

SHEPARD, Alan Bartlett, Jr. (born 1923, in East Derry, N. H.). A US astronaut, commander of the USNavy. Has been a Navy officer since his graduation from the US Naval Academy in 1944. From 1950 to 1953 and in 1955 worked at a USNavy test pilot school. Graduated from the Naval War College in 1958. Joined the NASA group of astronauts in 1959. Performed the US first suborbital space flight in a *Mercury* space capsule on May 5, 1961. The duration of the flight was 15 min.

SHOCK ACCELERATION. Brief (less than 1 s), but rapidly increasing (several hundreds or thousands of g/s) accelerations are experienced in case of spaceman's ejection, in case of emergency separation of the manned cabin from the launch vehicle and at the moment of spaceship touch-down on land. Large shock accelerations, if brief, are harmless to man. However, of great importance in this case are the direction of the acceleration, its rate of onset, total energy absorbed by the body, the seat contour, type of restraint system, correct selection of man's position, and training of the organism. If the vector of the acceleration coincides with or is close to the line of the vertebral column, the latter may be gravely damaged. Thus, in case of ejection (rate of acceleration onset 200—500 g/s) the tolerance limit is 20—22 g for a period of 0.1—0.2 s. This limit, however, is considerably higher, if the direction of the acceleration is transverse: in this case even accelerations of up to 45 g produce no visible damages. However, the parenchymatous organs, especially lungs, may suffer. In cases of emergency hard landing the rate of acceleration onset may reach 2000—3000 g/s. If the acceleration in this case exceeds 25 to 30 g, unfavourable symptoms of general commotion and local injuries may be observed. To reduce the force of possible shock at the moment of touch-down, shock-absorbers or retrorockets are used in addition to a parachute system.

SHORT-PERIOD DISTURBANCES. Disturbances with periods of one revolution of the disturbed celestial body. As a rule, the amplitudes of short-period disturbances are significantly smaller than those of LONG-PERIOD DISTURBANCES.

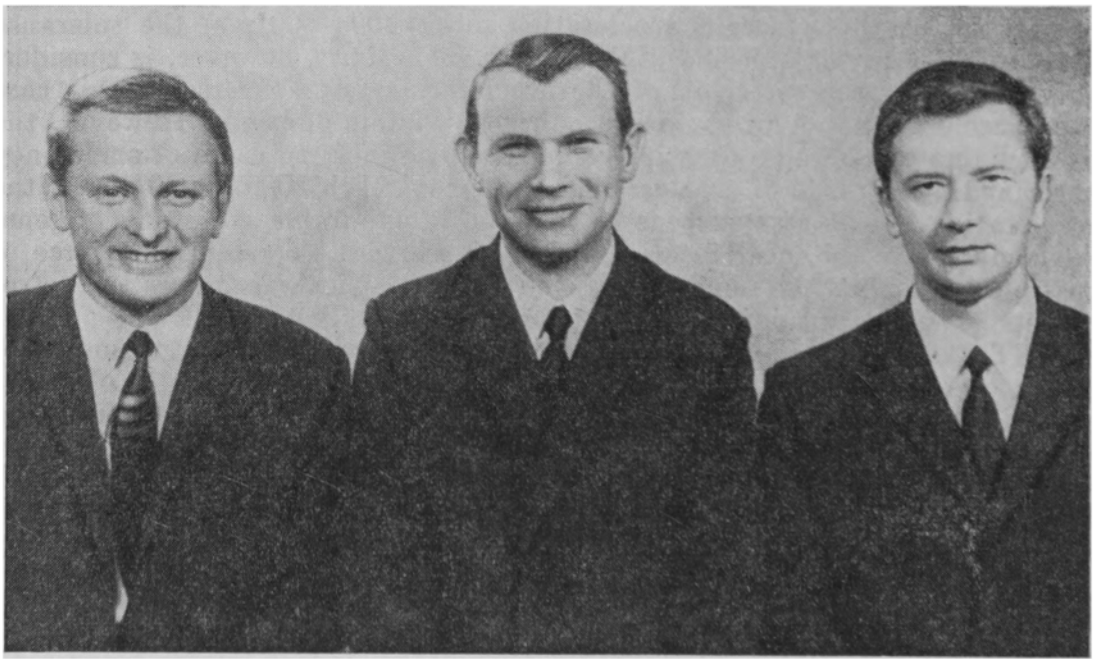
SIDEREAL PERIOD (sidereal revolution) of a planet. The time in which a planet of the solar system completes 1 revolution round the Sun.

SIGHTING DEVICES. Optical, TV, IR and other types of instruments used by a spaceman to check the angular attitude of the spaceship with respect to the REFERENCE POINTS in the course of manual orientation. Thus, the optical sighting devices of the *Vostok* and *Voskhod* spaceships made it possible to determine their attitude in respect to the Earth and to perform tri-axial manual orientation of the spaceship in orbit.

SIMULATION of space flight environment. Imitation of the conditions of space flight in ground laboratories. Each flight is preceded by a large series of simulations. Mathematical simulation is used to study the effect of space flight factors on spacemen, to solve the diagnostic problems of medical monitoring and forecasting of the spaceman's reactions. Simulation of man's interaction with the spaceship systems is highly important. Along with the simulation of the spaceman's operations with the spaceship's control panel, certain new channels of communication, such as the tactile channel, are investigated. In addition to visual and acoustic signals, electrodermal and

vibrational signals are employed in the emergency communication system, or to relieve the operator's visual and acoustic channels. Group interaction of crew members is simulated using the homeostatic principle in which the system stability is reached by adjusting a number of independent variables. It is the character of interaction of all the members of the group, not the individual peculiarities of the operators, that determines the successful solution of the problem. The systems of air regeneration, temperature control and air conditioning are installed in the spaceship cabin to simulate an environment adeqnate to the requirements of the spaceman's organism. As flights become more prolonged, simulation is more and more complicated. For interplanetary flights a closed ecological system is being developed, in which recycling of substances and energy is simulated.

SIMULATION OF YEAR-LONG SPACE FLIGHT. On November 5, 1967, in a special laboratory complex of a ground-based LSS comprizing a number of links, the first experiment began which envisaged a year-long stay in



G. A. Manovtsev, B. N. Ulybyshev and A. N. Bozhko

a sealed cabin of 3 researches: the physician G. A. Manovtsev (group leader), the biologist A. N. Bozhko and the technician B. N. Ulybyshev. The group used water and oxygen regenerated from products of vital activity of the researches (urea, transpiration moisture, and exhaled carbon dioxide). A year later, on November 5, 1968, the experiment was successfully terminated. During the experiment, different links of regeneration of gaseous environment were sequentially operated in the sealed cabin, while water was regenerated in ground installations. For nourishment the researchers used a spe-

cially designed ration comprising freeze-dried food and green vegetables (Khibin cabbage, garden cress, borage, and fennel) grown in a ground-based greenhouse during a certain period of the experiment proper. Sun light was simulated in the greenhouse. Ion-exchange resins saturated with nutrient substances substituted for soil. Solid biological wastes were removed from the sealed cabin. As a result of the experiment, data were received concerning human response to such factors as could be simulated in sustained life in the enclosed space of the sealed cabin, and links of a ground-based LSS were evaluated. All principal indices of health of the researches were within physiological norms.

SINGLE-AXIS ORIENTATION. A method of orienting a spacecraft according to which one of its axes is maintained at a fixed angular attitude, whereas the other 2 axes are directed arbitrarily. Single-axis orientation is sufficient for the solution of many problems, such as the ORIENTATION OF SOLAR BATTERIES. At full (tri-axial) orientation, all the 3 axes of the spacecraft are fixed in specific angular attitudes.

SINGLE-COMPONENT MONOPROPELLANT. A single substance, liquid or solid, capable of decomposing or re-combining in the rocket engine with generation of heat and gaseous reaction products. Single-component monopropellants include endothermic compounds containing both the oxidizing and the fuel elements. When a monopropellant is used, the propellant system of the rocket engine becomes simpler, but the penalty of lower specific impulse and higher explosion hazard must be paid. The monopropellants include hydrogen peroxide, hydrazine, methyl hydrazine, unsymmetrical dimethyl hydrazine, nitromethane, ethylene oxide, and other substances. They are generally used in auxiliary rocket engines (vernier, individual, etc.) and other auxiliary power units, e.g., in GAS GENERATORS for driving the turbine of a rocket engine. Monobasic cellulose nitrate is used as the single-component monopropellant for solid-propellant engines. The hypothetical MONATOMIC PROPELLANT and metastable propellant are also classified as single-component monopropellants.

SOCIETY FOR STUDYING INTERPLANETARY TRAVEL. Founded in Moscow in May, 1924, on the basis of the Interplanetary Communication Section of the Military Scientific Society of the N. E. Zhukovsky Air Force Academy. The Society was presided by: G. M. KRAMAROV (Chairman), M. G. Leiteisen (Secretary), V. P. Kapersky, M. A. Rezunov, M. G. Serebrennikov, F. A. TSANDER and V. I. Chernov. The Society had a charter. Its membership was about 200. K. E. TSIOLKOVSKY, V. P. VETCHINKIN, and M. Ya. Lapirov-Skoblo were among those who took part in the work of the Society. The Society concentrated the efforts of gifted engineers and designers on space flight problems and promoted popularization of the ideas of rocket engineering and space flight. It existed for about a year.

SOFT APPROACH of spacecraft. An approach of two spacecraft whose relative velocity is gradually brought down to a small value (in a perfect case, to zero). Soft approach is necessary for INSPECTION, MOORING, and IN-ORBIT ASSEMBLY. It requires a greater power consumption than INTERCEPTION.

SOFT LANDING of a spacecraft. The landing of a spacecraft which, by the moment of touch-down, has been decelerated to a very slow speed (in a per-

fect case, to zero). On planets with a sufficiently dense atmospheres this nca be accomplished by means of parachutes, carrier rotors (of the helicopter type) or other devices used for landing spacecraft on the Earth. If the planet has no atmosphere, the deceleration by rocket engines is a must for soft landing.

SOLAR ACTIVITY. The unstable phenomena on the SUN: sunspots, faculae, flocculi, chromosphere flares, prominences, coronal disturbances, sporadic electromagnetic radiations, temporary rise in the UV and X-ray emission, rise of the corpuscular radiation, etc. Practically all these phenomena develop within centres of activity dependent upon magnetic fields. All the solar activity phenomena have a yearly average of intensity and number, that varies on a cycle of 11.1 years mean duration. Cycles of solar activity having a much greater duration have also been detected (80 years and more). Sometimes the term "solar activity" includes the influence that the processes on the Sun have upon the condition of the Earth's ionosphere and radio short-wave propagation, as well as on such phenomena as night sky glow, magnetic storms, aurorae, etc.

SOLAR BATTERIES. Sources of electric power consisting of semi-conductor photo-electric cells arranged in batteries and capable of converting solar energy to electric energy. Solar batteries are widely used in spacecraft electric power systems. They take the form of one or more panels carrying a large

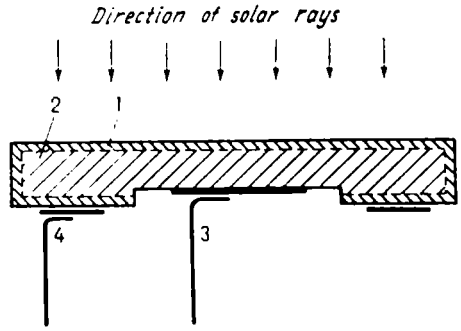


Diagram of solar cell.
1—*n*-type surface layer of silicon; *2*—*p*-type silicon wafer; *3*, *4*—electrodes.

number of solar cells, each cell having an area of several cm^2. The cells are so connected that they provide the necessary output voltage. Up-to-date solar cells have an efficiency of 8—10%. This corresponds to an output of about 100 W/m^2 of battery area. The power developed by solar batteries reaches several hundreds of W. Their service life is a year or more, being limited by meteoric errosion and radiation damage, especially large during solar flares or flight through the radiation belt of Earth.

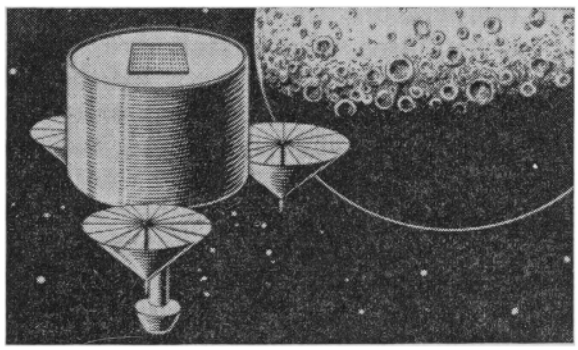
SOLAR CONSTANT. The energy, in cal, of solar emission beyond the atmosphere received per min on an area of 1 cm^2 normal to the direction of the Sun rays. The value of the solar constant depends on the distance from the Sun. At the distance of one radius of the Earth's orbit, the solar constant is 2.00 cal/cm^2 min.

SOLAR CORONA. See SUN.

SOLAR FLARES (chromospheric flares). A sudden and sometimes sharp increase in the light intensity of a separate area of the Sun atmosphere. Flares are normally seen in the rays of the hydrogen line of Liman (H_α), but the brightest flares are sometimes visible in general light against the background of the Sun's photosphere. The duration of solar flares varies: on an average flare lasts for a few tens of minutes, the most violent lasting as long as 1 h. The area embraced by solar flares is frequently as large as 10^9 km^2. Total energy emitted by the most intensive flares reaches 10^{31}—10^{32} erg. The solar flares are accompanied by a sharp rise in short-wave radiation from the Sun and emission of particles of different energies. Some (so-called proton) flares go along with especially violent fluxes of high-energy particles (cosmic rays of solar origin). The latter present special hazards for manned spaceships since high-energy corpuscles generate bremsstrahlung in the spaceship shell, whose dozes may prove lethal for the crew. Methods for forecasting solar flares are being developed.

SOLAR POWER PLANT. A source of electric power consisting of a converter of thermal energy into electric current (e.g., a THERMO-ELECTRIC GENERATOR) and a parabolic mirror which focuses the flow of the solar radiation on one of the surfaces of the converter to heat it. For the solar powerplant to operate, the axis of the parabolic mirror is to be constantly directed towards the Sun to a high degree of accuracy.

SOLAR ROCKET ENGINE. A rocket engine using solar energy to heat the working fluid (e.g., hydrogen). Thermal and photo-electric solar rocket engines are possible. They are in the stage of experimental development. In future, solar rocket engines may be used in outer space.



Heliodyne spacecraft powered by solar rocket engines (dummy).

SOLAR SAIL. A thin opaque film (e. g., a metallized polymeric one), stretched to form a large surface, installed on a spacecraft, and capable of imparting to it, under the effect of the pressure of solar radiation, a considerable velocity in the course of a sufficiently long period of time. It may find practical application in space flight. Solar sail was studied by Y. I. Perelman in 1915 and by F. A. Tsander in 1924.

SOLAR SENSOR. An instrument serving to determine the angular deviations of one of spacecraft axes with respect to the Sun. It usually comprisse opti-

cal and electronic elements and is used to solve the navigational problems by astronomical methods or as a position pick-off in certain orientation systems. The design of these sensors differs greatly depending on the accuracy and the field of view required.

SOLAR SURGES. See SUN.

SOLAR SYSTEM. That group of objects which consists of the Sun, 9 large planets with their satellites, more than 1700 known MINOR PLANETS, hundreds of known COMETS, and innumerable meteoric bodies (see METEOR, METEOR STREAM). The Sun is in the centre of the solar system, its mass being over 745 times the total mass of all other bodies making up the system. The Sun's attraction governs the motions of all the bodies travelling around it and holds them in their orbits; the main force for the satellites is that of the planet attraction. The large planets are MERCURY, VENUS, EARTH, MARS (the group of inner planets), JUPITER, SATURN, URANUS, NEPTUNE (the group of giant planets) and PLUTO. They revolve around the Sun in the direction of its axial rotation in almost circular (or, more exact, elliptical) orbits which are slightly inclined to each other and to the plane of the Sun's equator. Most planets rotate about their axes in the forward direction; Venus rotates very slowly in the reverse direction, Uranus seems to lie on its side. Most of the satellites of the planets move in the direction corresponding to that of their primaries' axial rotation. The satellites located far from a planet rotate in the reverse directions. Some groups of satellites resemble small-size planetary systems (satellites of Uranus, the large satellites of Jupiter). Small planets (asteroids) are located on the junction of the two groups of planets, between Mars and Jupiter.

The Sun is a star that in its deep interior emits nuclear energy and therefore maintains high temperature in spite of powerful radiation from its surface. All other bodies of the solar system are cold: the temperature of their surfaces is low and depends on heating by the solar rays.

SOLAR WIND. Continuous radial flow of plasma from the Sun, discovered by the observation of various phenomena such as: anomalous ionization and acceleration directed away from the Sun in the tails of comets of certain types; heating of the Earth's UPPER ATMOSPHERE and IONOSPHERE unrelated to solar UV radiation; the almost daily appearance of AURORAE; and the constant disturbance of the geomagnetic field at high latitudes. Explorations by space probes and satellites with highly elongated orbits furnished direct proof of the existence of a constant flow of plasma away from the Sun. The directional velocity of the plasma motion is several hundred km/s; the plasma concentration attains several tens of particles per cm^3; the energy of thermal (random) motion of ions, protons and α-particles is small compared with the energy of the directional movement and corresponds to a temperature of $\sim 10^5$ °K. The energy density of plasma always surpasses the local density of the magnetic field energy, which, considering the high electrical conductivity of interplanetary plasma, means that the solar magnetic field is in effect "frozen" into plasma, i.e., that the field's lines of force move together with plasma.

The theory of the plasma flow from the Sun was born when attempts were made to explain the main physical processes occurring during geomagnetic

storms. The works by Stermer, Chapman, Ferraro, Alven and others developed the hypothesis of sporadic local corpuscular fluxes. The results of studies of the solar corona and its relation to corpuscular radiation made it possible to find a new approach to the problem. The development of the solar wind is probably due to the energy in the form of waves received by the corona. The heating of the corona is not balanced by its radiation inasmuch as the density of the corona declines with height. As a result, the temperature of the corona rises, which causes the outflow of gas from the Sun with the removal of excess energy (dissipation of the corona). To modern concepts, the solar wind is essentially a continually expanding solar corona (the pressure of the heated gas causes steady hydrodynamic outflow). Up to a certain distance the flow is assumed to be isothermal, i.e., the sources of heat and heat conductivity carrying energy from the inner corona are considered to be at work. Beyond this boundary the flow becomes adiabatic, i.e., without heat losses or transference. Continuous acceleration of the gas causes transition of subsonic velocity into supersonic. At corona temperature of 1,200,000°K the calculated value of the radial outflow velocity closely agrees with that actually observed in the solar wind (300—500 km/s). Most scientists accept the hydrodynamic mechanism of acceleration of solar plasma suggested by Parker, although his simple model of plasma outflow is regarded as improbable. To this day there are no models of outflow which allow for the influence of magnetic fields in solar plasma (the assumption is that the magnetic field does not interfere with dissipation and is deformed by the plasma flow). Furthermore, according to Parker, a steady solar wind constitutes a homogeneous plasma flow, while according to other works, this flow consists of separate corpuscular fluxes or jets.

To the first approximation, it may be assumed that it is the solar wind that controls the dynamic processes in interplanetary space by drawing in the lines of force of the Sun's magnetic field. Various parts of the plasma flow that have left a definite area of the Sun's surface at different moments of time find themselves at a given moment on a spiral whose degree of twist is determined by the radial velocity of the outflow. Insofar as the lines of force of the solar field move together with the plasma, they should also have the same spiral form (if they remain connected with the Sun). In the framework of this concept the solar wind "blows" continually, while the fluxes responsible for storms are connected with recurrent or isolated fluctuations in the solar wind force.

SOLID PROPELLANT (sometimes called gunpowder). In the past, solid propellant was loaded into the engine chamber as powder pressed into grains and wafers (this still being practiced for unguided rockets). Today solid-propellant engines are filled with semi-viscous substances that solidify with time and adhere firmly to the rocket walls, thus protecting the latter against hot gases. The following main types of solid propellant are generally used: HOMOGENEOUS SOLID PROPELLANT (double-base), HETEROGENEOUS SOLID PROPELLANT (composite) and intermediate types. To ensure a smooth burning and high reproducibility of thrust, the burning rate of a solid propellant should be virtually independent of pressure and temperature. The solid propellant should ignite easily; have an acceptable burning

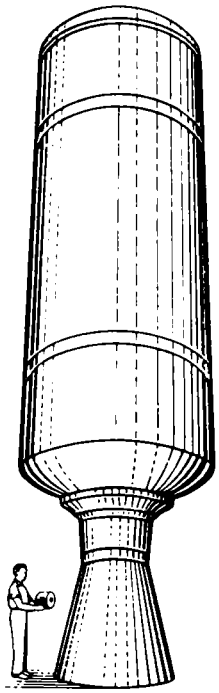
rate, good reproducibility of combustion characteristics, suitable physical and mechanical properties excluding the possibility of crack formation and occurrence of other defects of the charge; be explosion-proof and stable in long-term storage. The specific impulse of solid propellants is lower than that of liquid propellants, whereas their density is greater. Solid propellants offer several advantages in service.

SOLID-PROPELLANT CASE. The body of a solid-propellant rocket engine. It consists of a shell of cylindrical or other shape and two bulkheads. The shell and the bulkheads are usually sheet-metal parts assembled by welding with subsequent heat treatment. The long cylindrical shell may be welded from steel strip. Solid-propellant cases are made of strongest steels, sometimes of glass-reinforced plastics by winding of thin (up to 0.009 mm) glass fibres or bands impregnated with various resins. The plastic cases are lighter than the steel ones, but require more thorough control of production processes. The nozzles of solid-propellant engines are made of various materials; the part of the nozzle near the throat, where thermal stresses are highest, is made of graphite, refractory metals or their alloys. The area beyond the throat, where stresses are moderate, is made of steel, plastics, or graphite.

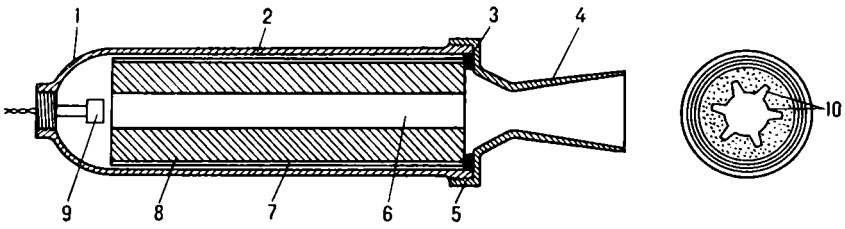
SOLID-PROPELLANT ENGINE. A rocket engine firing a solid propellant. It has found wide application in missile artillery and a limited one in space flight. This is the oldest thermal motor. The thrust of solid-propellant engines ranges from several g for MICRO-ROCKET ENGINES to hundreds of t for high-power ones. In these engines the total charge of the propellant is loaded into the combustion chamber. After ignition the combustion usually goes on till the propellant burns out, and thrust changes are governed by the laws regulating the combustion of propellant; thus, they remain not controlled. Solid-propellant engines are simpler in design and operation, than liquid-propellant ones, but lack their advantages, *viz.*, high specific impulse, controlable thrust and re-startability. The thrust chambers of solid-propellant engines are not cooled, so in cases of long-operating engines the part of the nozzle near the throat is made refractory. Use is also made of ABLATION COOLING or heat accumulation, shielding by refractory materials, etc. High-thrust solid-propellant engines are used to power certain launch vehicles in the USA (*Scout*, *Thor*, *Titan*), France and Japan. They are also employed as retro-rockets, emergency and mid-course correction engines, etc.

SOLID-PROPELLANT ROCKET. The rocket whose engine burns a solid propellant, i.e., a multi-component mixture containing fuel and oxidizer. The propellant charge consists usually of several cylindrical wafers inserted directly into the combustion chamber, the latter serving as the main structural element of the rocket body. If the engine is intended for longer periods of operation (tens of s), the charge takes the form of a single wafer with an axial channel provided in it. Solid-propellant rockets, though of simpler design than liquid-propellant rockets, show lower efficiency of the powerplant (poorer SPECIFIC IMPULSE). Rockets of this class may be used as certain stages of space rockets.

SOLSTICE, winter and summer. Two diametrically opposite points at which the Sun's DECLINATION reaches a maximum absolute value. Near these points, the solar declination varies very slowly, appearing to halt altogether for



(a)



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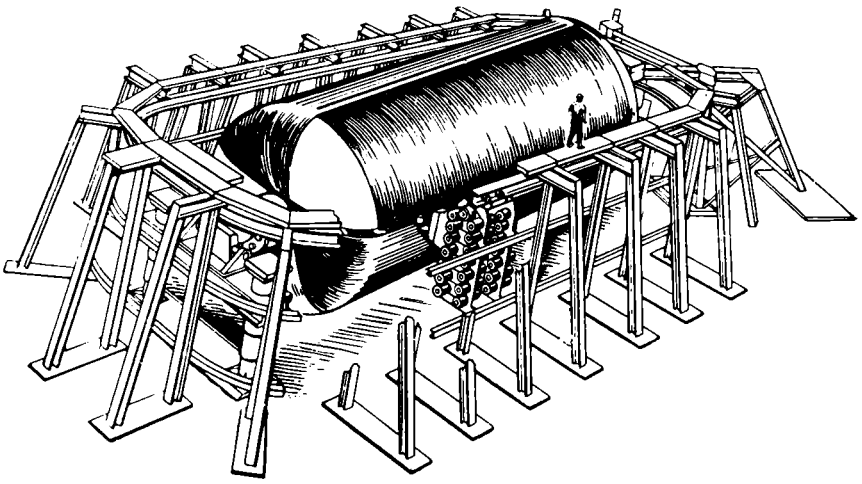


(c)

Solid-propellant rocket engine: (*a*) solid-propellant engines of different sizes (the large engine is 3 m in dia, the small one, 250 mm); (*b*) schematic diagram of solid-propellant engine; (*c*) manufacture of a solid-propellant case (dia 6.6 m, length 16.5 m) by winding strips of glass-reinforced epoxy plastic.

1—forward part of engine; *2*—cylindrical combustion chamber; *3*—gasket; *4*—nozzle; *5*—thread connection; *6*—perforation in grain; *7*—protective coating of grain surface; *8*—propellant grain; *9*—igniter; *10*—combustion surface.

several days at a single noon altitude. Winter solstice occurs on about December 22, summer solstice, on about June 22.

SORBENTS. Materials capable of absorbing gases, vapours and dissolved substances from various media. Widely used in spaceship LSS.

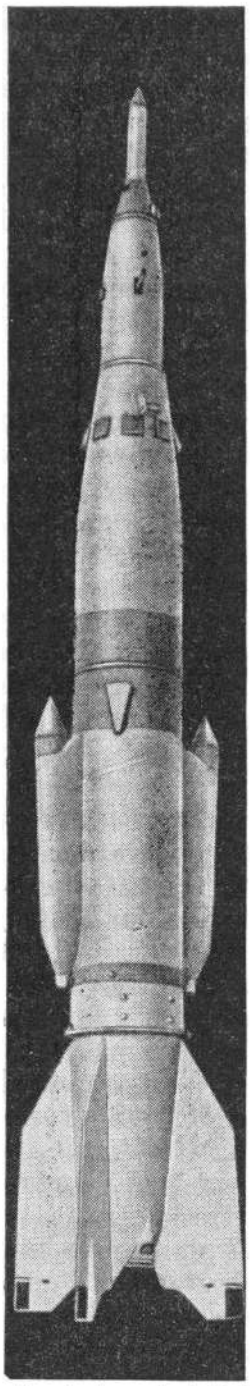
SORPTION. Physico-chemical process of absorption of gases, vapours or dissolved substances by a sorbent.This term covers the processes of absorption, adsorption, capillary condensation and chemo-sorption in most cases interconnected. These processes are employed in LSS in atmosphere cleansing, oxygen regeneration, waste utilization, etc.

SOUNDING ROCKET. A rocket for exploration of the upper atmosphere, space, the Earth, etc. The probes are normally launched for vertical flight to the height from a few tens to a few thousands of km. Many probes are equipped with a jettisonable nose wherein some of research equipment is brought down to the Earth. The USSR has been systematically launching probes since 1949. A great number of probes have also been launched by the USA and some other countries.

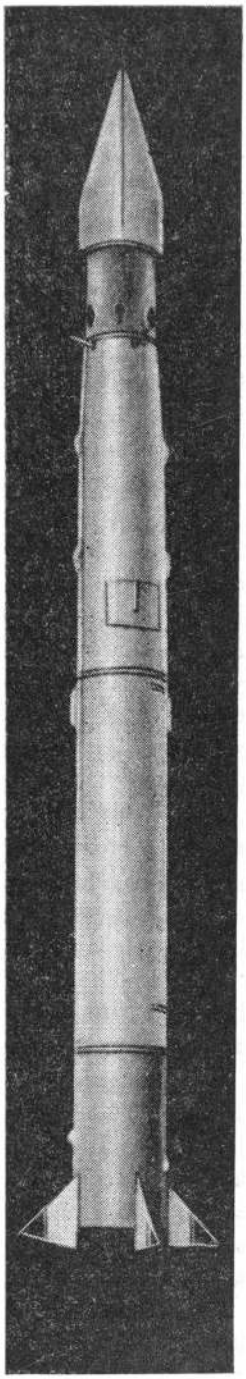
SOVIET AUTOMATIC INTERPLANETARY STATIONS. From 1959 up to May 1, 1969, 27 automatic interplanetary stations of different types were launched in the USSR. Among these were: *Luna-1* (world's first artificial planet); *Luna-2* (first spacecraft to impact the Moon); *Luna-3* (first spacecraft to photograph the far side of the Moon); *Mars* and *Venyera* (flight missions to other planets); *Luna-9* (first to accomplish a soft Moon landing); *Luna-10* (first artificial lunar satellite), and *Zond.* These interplanetary stations sent back a wealth of scientific information on the physical conditions in outer space and on the Moon, and helped to find answers to such problems of deep space flight as radio communication, flight control, orientation and navigation in flight to other celestial bodies, landing on the surfaces of other celestial bodies, and temperature control at different distances from the Sun. Apart from their purely scientific value, the data obtained are needed for future manned flights to other celestial bodies.

SOVIET EARTH SATELLITES. The world's first artificial Earth satellite was the Soviet *Sputnik-1*, orbited on October 4, 1957. 240 sputniks were launched by the USSR as of October 4, 1967, this number growing to 381 by Oct. 4, 1969 (see EARLY SOVIET EARTH SATELLITES, VOSTOK, VOSKHOD, COSMOS SATELLITES, ELECTRON, MOLNIYA-1, POLYOT, PROTON and SOYUZ). The weight of Soviet satellites comes up to 17 t (*Proton*). They orbit at altitudes of 70,000 km (*Electron*) and over. The flights of the Soviet satellites made it possible to obtain many new data on outer space and the Earth, to send man into space, to improve the design of satellites intended for different missions, and to perfect space-borne equipment. A number of satellites are systematically used for solving problems of national economy, e.g., long-distance communications, TV broadcasting, and weather forecasting.

SOVIET GEOPHYSICAL ROCKETS. High-altitude exploration rockets whicb have been systematically launched in the Soviet Union since 1949 with the purpose of geophysical and other investigations. Soviet geophysical rockets of *B-2-A* type are intended for investigating the upper atmosphere, taking photographs of solar spectrum, carrying out biomedical investigations by lifting animals (dogs), and for other scientific experiments. The weight



Soviet geophysical rocket *B-2-A*.



Soviet geophysical rocket *B-5-B*.

of the instrument compartment is 1340 kg, that of the geophysical container, 860 kg. The length is 20 m, the maximum dia of the body, 1.66 m. The ceiling with the payload of 2200 kg is 212 km.

Soviet meteorological rockets

B-5-B type rockets are intended for astrophysical, geophysical, biomedical, ionospheric and other investigations. The rockets were used to develop the means of landing the animals from high altitudes. Their payload weight is 1300 kg; length, 23 m; maximum body dia, 1.66 m; ceiling, 512 km. Soviet geophysical rockets obtained important data on the structure of the upper atmosphere and ionosphere, and on the composition of cosmic rays; they were instrumental in the investigation of the behaviour of living organisms under rocket-flight conditions, as well as in photographing of the solar corona and other scientific experiments.

SOVIET METEOROLOGICAL ROCKETS. High-altitude probes launched systematically by the USSR since 1949 for weather research including measurement of temperature, atmospheric density and pressure, wind velocity and direction at different altitudes. They are a modification of geophysical rockets. *MP-1* (*MR-1*) Soviet meteorological rockets have a ceiling of 100 km; their nose compartment carries thermal and diaphragm manometers, resistance thermometers, bolometers, a radio telemetry system, storage batteries, and other types of equipment. On reaching the design altitude, the nose compartment separates from the body and is parachute landed. The *M100* Soviet meteorological rockets have two solid-propellant stages; their take-off weight is 475 kg and they have a ceiling of 100 km with a scientific package of 15 kg. The small *MMP-06* (*MMR-06*) meteorological rockets are single-stage solid-propellant vehicles with a take-off weight of 135 kg and a ceiling of 60 km with an instruments package of 5 kg. Soviet meteorological rockets are launched from both USSR territory and other areas (Arctic and Antarctic regions or hydrographic vessels in the oceans).

SOVIET METEOROLOGICAL SATELLITES. Spacecraft designed for regular collection of the meteorological data necessary for an efficient weather service and for scientific investigation. These satellites of the *Cosmos* and *Meteor* series are comprised in the *Meteor* meteorological system. A number of systems of the weather satellites were flight tested in 1963—64 on board satellites of the *Cosmos-23* type. Created and tested in 1966 was *Cosmos-122* carrying a set of instruments for meteorological observations. The launching of *Cosmos-144* and *Cosmos-156* on February 28 and April 27, 1967, respectively, inaugurated operation of the *Meteor* system; *Cosmos-184*, *Cosmos-206* and other satellites were subsequently included in this system. Their orbits are nearly circular at a height of ~600—700 km, inclined at 81°. Continuous orientation of the satellites in the orbital system of coordinates keeps their longitudinal axes in local vertical. The systems on board are energized by solar batteries mounted on two panels whose planes are kept. The meteorological equipment comprises the following systems: two TV cameras for observation of the day-time side of the Earth (band of ground observable: ~1000 km; resolution: ~1.25 km); IR equipment of TV type (band of ground observable: ~1100 km; resolution: ~15 km; operational waveband: in the water-vapour window of 8—12 μ; temperature sensitivity ingredients: 2—3°C); 4 actinometric instruments of both scanning and wide angle types for measuring radiation fluxes emitted by the Earth (band of ground observable: up to 2500 km; operational wavebands: 0.3—3μ, 3—30μ, and 8—12μ). In one orbit the equipment provides data on nebulocity over ~8%

and on radiation from ~20% of the territory of the globe. The information thus obtained is stored in space-borne memory units to be transmitted to the Earth during the next session of radio communication. Soviet meteorological satellites regularly provide information for the weather service used by the national economy and for international exchange.

SOVIET SATELLITE-SPACESHIPS. A series of 5 unmanned spaceships launched in 1960 and 1961 into satellite orbits in preparation for manned space flight, i.e., to prove the spaceship design and the operation of the space-borne equipment responsible for the spaceman's safety and vital activity in flight and his return to Earth. These spaceships weighed 4540—4700 kg and flew at altitudes of 180—370 km. *Spaceship-1* was launched on May 15, 1960. On August 19, 1960, *Spaceship-2* went into orbit with the dogs Belka and Strelka on board. After completing a round-the-clock flight, the spaceship returned the dogs to Earth by ejecting their parachute-borne container. *Spaceship-3* was launched on December 1, 1960. On re-entry into the Earth's atmosphere, it failed to take the correct trajectory and came to an end in the dense layers of the atmosphere. *Spaceship-4* was sent into orbit on March 9, 1960, with a dummy spaceman and the dog Chernushka in its cabin. It was successfully landed. *Spaceship-5* was launched on March 25, 1961, this time with the dog Zvezdochka and a dummy spaceman in its cabin. It also successfully landed in the planned area.

Manned spaceships *Vostok* (6 launches), *Voskhod* (2 launches), and *Soyuz* (4 launches) brought 16 men into space in the period of 1961—68.

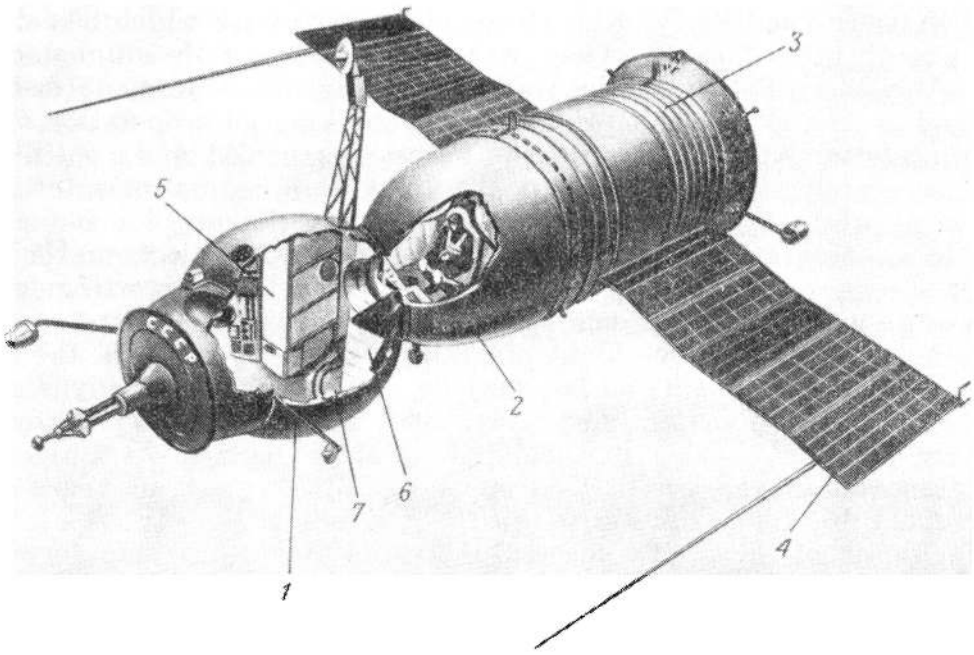
SOYUZ. The name of a new series of multi-seater Soviet spaceships for sustained flight, orbital manoeuvring, approach and docking. The *Soyuz* programme envisages wide-scale scientific and technological investigation in circumterrestrial space and, subsequently, assembly of manned orbital stations. The *Soyuz* spaceship comprises an orbital compartment housing experiment and recreation quarters, a re-entry body accommodating the crew cabin and an instrument-and-systems compartment housing most of the equipment and two vernier engines with a thrust of 400 kg each. The orbital compartment communicates with the re-entry body through an air-tight hatch. The total volume of the two compartments is ~9 m^3. The re-entry body has a thermal-protective coating; its shape ensures re-entry with aerodynamic control. Within the re-entry body are the seats for the crew, the control panel, re-entry control system, radio equipment, life support system, parachute systems, and other installations. The re-entry body has several low-thrust rocket engines for re-entry control and a solid-propellant engine for soft landing. The re-entry phase is controlled by adjusting the direction of lift force so that deceleration is reduced to 3—4 g and much greater accuracy of landing is achieved. The soft-landing system ensures a landing speed not exceeding 2—3 m/s. The attitude and flight control system provides spatial orientation of the spaceship, control and stabilization in powered flight, approach to another spacecraft and manoeuvring near it; the system can be controlled either automatically or manually. The automatic docking system of this spaceship was tested during twin flights of *Cosmos* satellites. The equipment on board is energized by solar batteries mounted on 2 deployed panels. The set of radio equipment determines the orbital parameters,

receives commands from the Earth, ensures two-way communication with the Earth, transmits standard TV images (from 4 space-borne cameras), and telemetry data. The spaceship is equipped for independent flight and piloting. Its powerplant permits manoeuvring at altitudes up to 1300 km.

Soyuz-1 was placed in orbit on April 23, 1967, with the aim of development testing of its systems and components in space flight conditions. It was piloted by Pilot-Cosmonaut V. M. Komarov, Hero of the Soviet Union, engineer-colonel, who had made a flight in a *Voskhod* spaceship. The orbit perigee was 201 km, the apogee was 224 km. During the test flight lasting over 24 h, V. M. Komarov fulfilled the programme for testing the systems of the new vehicle. On April 24 *Soyuz-1* made a safe re-entry into the dense layers of the atmosphere and eliminated the first cosmic velocity. However, a failure in the parachute system led to a faulty deployment of the main parachute at an altitude of ~7 km. This resulted in a high descent velocity, a crash on landing and the death of V. M. Komarov.

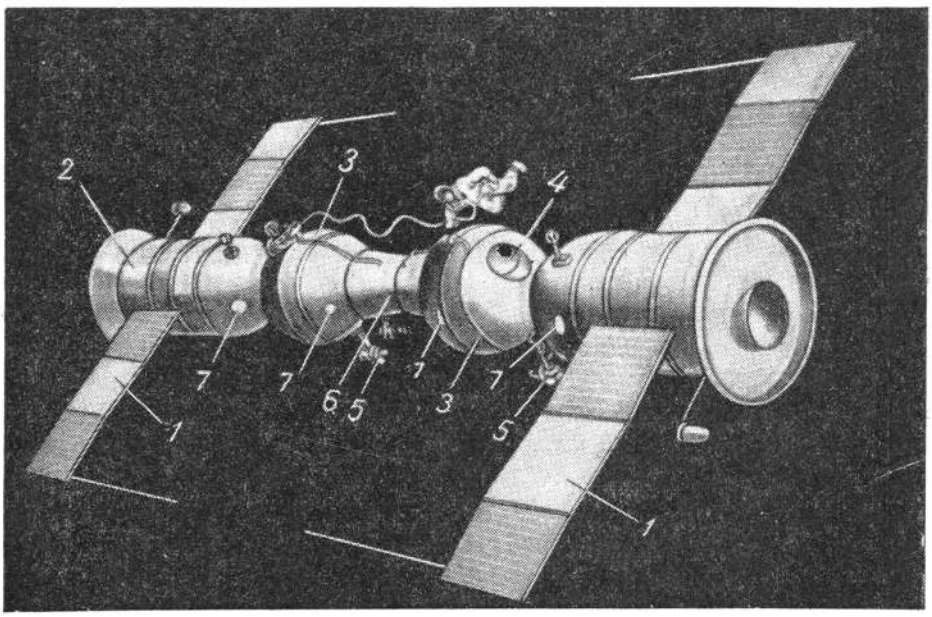
Soyuz-2 and *Soyuz-3*. *Soyuz-2* was injected into orbit on October 25, 1968; it had a perigee of 185 km, an apogee of 224, and an inclination of 51.7°. As *Soyuz-2* passed over the space centre on October 26 at 11 h 34 min Moscow time, the *Soyuz-3* piloted by Pilot-Cosmonaut Lieutenant-Colonel G. T. Beregovoy was launched. Its orbit had a perigee of 205 km and an apogee of 225 km. After going into orbit, *Soyuz-3* performed a radio search for *Soyuz-2* and automatic approach to a distance of 200 m. Subsequent approach and manoeuvring of *Soyuz-3* near *Soyuz-2* were manually controlled by the cosmonaut. Then the spaceships separated to a distance of 565 km and approached each other again. On completing these joint experiments, *Soyuz-2* landed in the predetermined area, re-entry being effected with aerodynamic control and employment of the soft-landing system. The *Soyuz-3* continued its flight; the cosmonaut tested different modes of orientation, made regular TV reports from orbit, performed a great many scientific and technological experiments, including observation of the stellar sky, the Earth and celestial luminaries, photographing of the cloud canopy and snow cover, of daytime and twilight horizons of the Earth, detection of typhoons and cyclones, and biomedical investigations. During the 36th revolution the orbit was corrected so that it would have a perigee of 199 km and an apogee of 244 km. On October 30, 1968, the *Soyuz-3* made a re-entry with aerodynamic control and at 10 h 28 min Moscow time effected a soft landing in the predetermined area of the USSR.

Soyuz-4 and *Soyuz-5*. *Soyuz-4* was orbited on January 14, 1969. It was piloted by Pilot-Cosmonaut Lieutenant-Colonel V. A. Shatalov. The orbit perigee was 173 km, apogee 225 km, inclination, 51° 40′ (after correction of orbit during the 4th revolution the perigee became 207 km and the apogee, 237 km). *Soyuz-5* was injected into orbit on January 15 carrying a crew of three—Colonel B. V. Volynov, commanding officer; A. S. Yeliseyev, candidate of technical sciences, space engineer; and Lieutenant-Colonel Ye. V. Khrunov, test engineer. The orbit parameters were: perigee, 200 km; apogee, 230 km; inclination, 51° 40′. On January 16, after automatic approach, the two spaceships were manually docked (at 11 h 20 min Moscow time). Thus the world's first experimental space station was assembled in orbit



Soyuz-3 spaceship.

1—orbital compartment; *2*—crew cabin; *3*—instrument-and-system compartment; *4*—solar batteries; *5*—cosmonaut's working area; *6*—recreation quarters; *7*—entrance hatch.



Orbital station.

and began functioning. When docking was completed, Cosmonauts A. S. Yeliseyev and Ye. V. Khrunov made a space walk which lasted 37 min and passed into *Soyuz-4*. They wore space suits with autonomous life support systems. Following the transfer, experiments were made in orientation and control of the orbiting station and checking joint operation of spaceborne systems. At 15 h 55 min the spaceships parted and continued the flight separately. Performed during the flight were manual orientation, correction of orbits, scientific and technological experiments, biomedical investigations, observations of geological and geographical objects on the surface of the Earth, observations of celestial luminaries, TV reporting from the spaceship, movie pictures and photographs, navigational measurements, and other events. After the flight programme had been fulfilled, the *Soyuz-4* with the three cosmonauts on board made a re-entry with aerodynamic control, entered the predetermined area, and, at 9 h 53 min Moscow time, January 17, 1969, landed in the territory of the USSR, 40 km northeast of Karaganda. *Soyuz-5* with Cosmonaut B. V. Volynov on board landed on January 18, 1969, 200 km southeast of Kustanai.

The flights of the *Soyuz* spaceships are an important step forward in improving manoeuvrable manned spaceships and assembly of orbital stations of significance in research and the national economy.

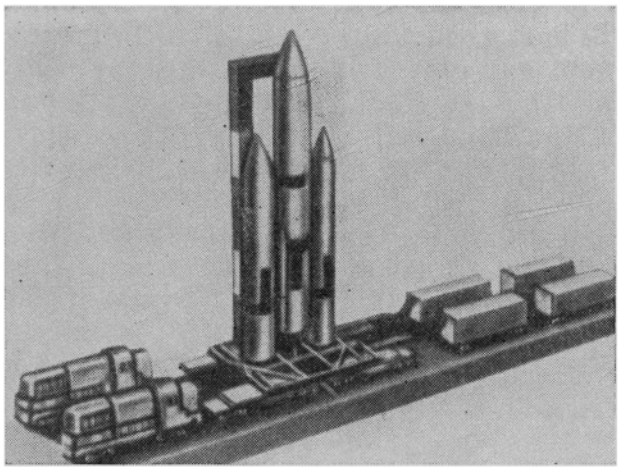
SPACE. A broad concept used to designate what extends beyond the limits of the Earth's atmosphere. Usually it does not imply outer space as a whole (see COSMOS), but some particular regions of it characterized by widely differing properties—near-terrestrial space, interplanetary space, etc. These terms apart, such rather indeterminate terms are used for a general characteristic of manned flight environment as "near space", "far-out (open) space" describing the flight altitude relatively to the Earth and the emergence of the spacemen into conditions characterized by the absence of atmosphere, terrestrial gravity pull, etc. The International Aeronautical Federation (FAI) has decided to arbitrarily apply the term "space flight" to flights at altitudes no less than 100 km.

SPACE-BORNE PROGRAMME TIMER. An electronic unit installed on board a spacecraft to deliver command pulses to the spacecraft systems at predetermined moments of time. The command pulse programme (sequence of commands and intervals of time between them) may be pre-determined (e.g., during preparations for flight) or set up during flight by signals sent from the Earth over the spacecraft command radio line. In the latter case, a storage unit must be incorporated to remember the introduced programme. The programme timer permits the spacecraft to be controlled during the periods when radio communication from the ground stations is impossible or discontinued. In the up-to-date spacecraft it comprises an involved transistorized electronic system.

SPACE CENTRE. A complex of structures, equipment and ground areas intended for assembling, preparing and launching space vehicles, measuring their flight trajectories, sending commands, and receiving and processing telemetry information. Some space centres incorporate ground plots for dropping the burn-out stages of launch vehicles. The basic components of a space centre are: maintenance area, launch complex and flight control

range. Each of these components is an intricate complex of equipment and structures intended for accommodating this equipment and providing the requisite conditions for operating it.

The equipment of a space centre is usually divided into ground system equipment and general-purpose technical equipment. The former includes diverse and multitudinous types of equipment for rocket transportation, transfer, assembly, testing, installation on the launcher, loading with propellants and charging with compressed gases, thermostatic control, preparation for launching, launching proper and flight control of the space vehicle. The general-purpose technical equipment includes electric power, lighting, heating, ventilating and fire-protection equipment, as well as systems of

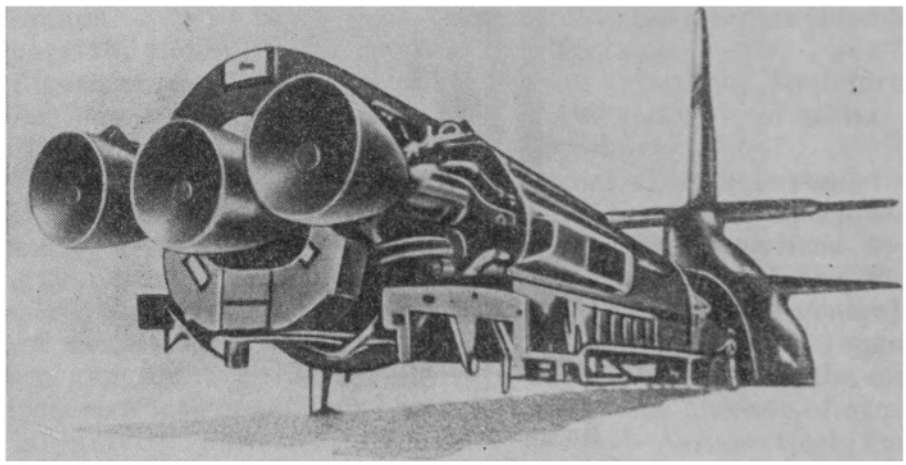


Rocket transportation

room pressurization and gas-analyzing, intercommunication and water supply, industrial and utility sewerage, lifts, and remote and automatic control systems. For each type of a launch vehicle the space centre has a maintenance area, one or several launch complexes and, sometimes, some elements of the flight control range. The auxiliary and service facilities and systems of a space centre include zones for storing the propellants and for producing cryogenic propellants and nitrogen and chemical laboratories for their analysis; a power supply system (heat and power supply plants, power stations, transformer stations and electric transmission lines), a settlement with headquarters and administrative services of the space centre, a training centre and a complex of utility and cultural establishments; a water supply system including a pumping and purification plant at the nearest river; a system of intercommunication of all the units and services with the headquarters, launch complexes, maintenance areas, and the launch control centre; a repair base and storage facilities; an airfield; access routes and transport communications including a railway terminal. Some space centres have waterways, i.e., canals for delivering the launch vehicles or stages thereof by motor barges, and water basins with piers for unloading

and manoeuvring of the barges. A space centre may employ several tens of thousands of men.

The *maintenance area* is a ground area with access routes and a complex of structures accommodating general-purpose technical equipment and ground system equipment. The facilities of the maintenance area receive, store and assemble launch vehicles and space bodies, ensure their testing, filling the space body systems and mating space bodies with launch vehicles. Located within the maintenance area are the vehicle assembly building (VAB), or a vertical assembly building, a space body assembly building, a space body filling station, a compressor station with a receiver room, an electrical power or transformer substation, and service buildings. A maintenance area for launch vehicles with solid-propellant boosters may include



Loading a rocket into an aircraft (USA).

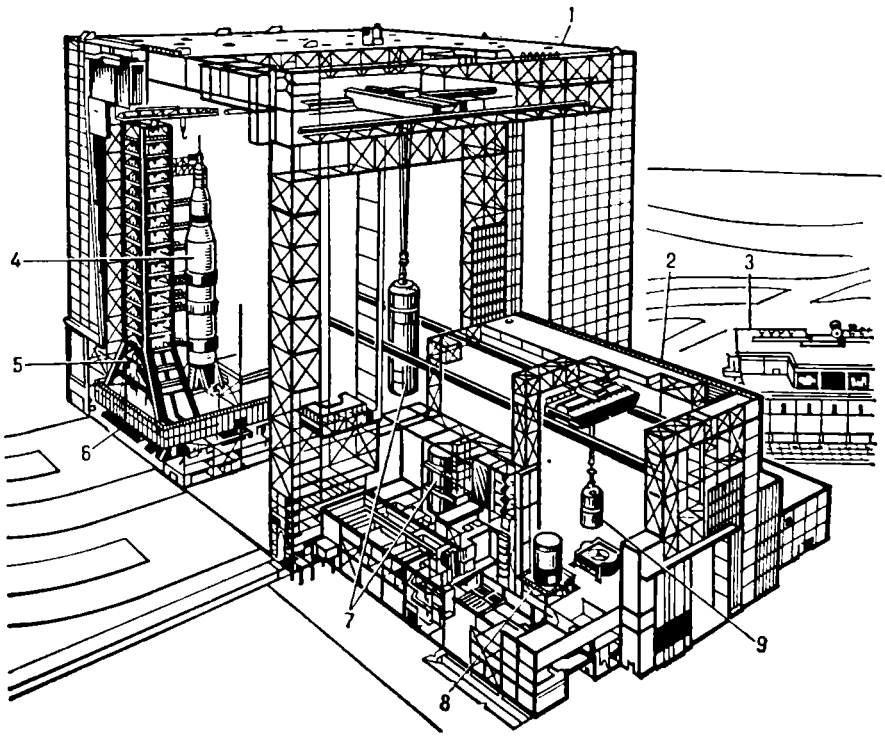
additionally a primary storage for sections of solid-propellant boosters a building for their inspection, a storage space for the ready-to-use sections, and a building for assembly and mating of solid-propellant boosters. Stages and units of the launch vehicle and spacecraft are delivered from the manufacturer factories to the VAB of the maintenance area. The launch vehicles are usually shipped by rail or over hard-surface motor roads; aircraft are also used for this purpose, so the ground equipment of the space centre must include rocket-handling dollies and truck tractors for hauling the launch vehicles, their stages and units from the airfield to the maintenance area. Launch vehicles or their elements are shipped by rail in box cars with a removable top for unloading by means of bridge cranes and cross-arms, or with an end door and a sliding frame for unloading without a crane; or else they can be carried on flat cars with a removable cover. All the transport facilities have cradles, grabs and supports to secure the launch vehicles; for damp-

ing the jolts on the rail joints, the cradles of the railway cars are provided with shock absorbers. As the launch vehicles grow in size, waterways will probably find wider application. To avoid transportation of supergiant launch vehicles, their large-size components (e.g., propellant tanks) are welded together at the assembly factory of the space centre, which carries out some of the functions of a space wharf. A space wharf will serve for manufacture and launching of space vehicles in future, when the vehicles' sizes grow to make them completely unfit for transportation.

There are three methods for the launch vehicle assembly: (1) horizontal assembly of individual stages, assembly of the launch vehicle proper and mating of the space body to it, realized in the VAB; (2) horizontal or vertical assembly of individual stages of the launch vehicle in the VAB, their transportation to the launch area, and vertical assembly of the vehicle on the launcher with subsequent mating of the space body; and (3) vertical assembly of individual stages and their integration into the launch vehicle on the upright launcher tower installed in the VAB. The 1st method is the most widely used and economical one, but involves a difficult task of erecting the vehicle (horizontal when delivered from the VAB) on the launcher; a disadvantage of horizontal assembly lies in that all the tests of the launch vehicle in the VAB are conducted in the non-operational (horizontal) position which calls for re-testing all systems separately and in complex after the vehicle is installed on the launcher, since erection of the vehicle and its mounting on the launcher may cause failures. The 2nd method of assembly is suitable for the space centres located in areas with mild climate. By this method only individual stages of the launch vehicle are assembled in the VAB; this cuts down substantially both the size and the construction cost of the VAB and dispenses with the necessity for special means of transport and costly roads for carrying the fully integrated vehicle from the VAB to the launch pad. However, assembling the vehicle on the launcher keeps the launch complex a long time unavailable for other vehicles, thus reducing the number of possible space launchings from one launch pad. Hence, this method calls for the construction of an additional number of launch complexes. Cost estimates have shown that the construction cost of a space centre can be reduced materially if the same launching programme is carried out from a single launching site. For this purpose the vertical assembly of the vehicle should be transferred from the launcher into a tall VAB having a number of assembly bays, and the fully assembled vehicle should be carried to the launching pad in a vertical position. In the 3rd method, vertical assembly of the launch vehicle is performed in the high-bay area of the VAB (referred to as "vertical assembly building"), directly at the launcher tower which later is carried to the launch pad together with the launch vehicle. The vehicle stages are assembled in the low-bay area of the VAB whence they are taken by bridge cranes into the high-bay area comprising several vertical assembly bays. Assembly operations are performed by bridge cranes with the aid of extensible platforms that go to make a number of circular work floors; some of these platforms can move in the vertical direction. A disadvantage of this method resides in the necessity for constructing a tall VAB which is subject to strong wind loads and is difficult to design and construct.

Space centre

The largest of the vertical assembly buildings today is 160 m high, its effective floor area is 140,000 m^2 and cubage 3,540,000 m^3 in the variant with 4 high bays, which is to become 5,040,000 m^3 in the variant with 6 high bays (USA). The framework of such a building is made of steel, with aluminium alloys used for the walls and the roof. Another disadvantage is the complexity of transportation of an erected launch vehicle jointly with the umbilical tower because of high wind loads on the entire structure. The launch vehicles are transported over a special two-lane crawler-way by a crawler transporter, or over a double-track railway on a railway launching platform. There are projects to assemble the rocket vertically in a barge-borne vertical assembly building, to carry it along a canal to the launching



Vertical assembly building:

1—high-bay area; *2*—low-bay area; *3*—launch control centre; *4*—assembled launch vehicle; *5*—umbilical tower; *6*—crawler transporter; *7*—second stages of launch vehicle (one is being checked out, the other is being carried by crane); *8*—third stage of launch vehicle (being checked out); *9*—space body.

site, and to launch from the barge after pumping water out of the launching portion of the canal and seating the barge or rigid supports. The use of the 3rd method can be justified only for the launch vehicles which were designed for vertical assembly and cannot, therefore, be assembled horizontally and lifted from the horizontal position into vertical. Apparently, the 3rd method will be more favourable than the first one only for the supergiant launch vehicles whose heights and diameters are very large.

The launch vehicles with liquid-propellant engines and solid-propellant boosters require the construction of two VABs: one for assembling and testing the liquid-propellant rocket and the other one for assembly and mating of the solid-propellant boosters. The boosters are mated by powerful bridge cranes of 300-ton or larger capacity. Horizontal assembly of the vehicle stages is carried out on assembly trolleys moving, as a rule, over the rails inside the VAB. After testing the individual stages, the vehicle is horizontally assembled in an assembly jig fitted with a complex of transversal and longitudinal beams, and the use of bridge cranes and mating trolleys is made. The bridge cranes used in the VAB will lift a load of up to 250 t to a height of up to 140 m (for vertical assembly). To increase the reliability of the cranes, the load is lowered at a motorizing duty (free lowering with brakes applied is not allowed); these cranes have twice as many motors as conventional cranes; the load is lifted by two motors (hoisting is ensured even if one of the motors fails; likewise, if part of the hoisting mechanism becomes inoperative, the other half of the blocks and ropes will sustain the full load).

After assembly, components and subassemblies of the launch vehicle are tested, followed by a system integration test, for which purpose the VAB is duly equipped with the appropriate check-out instruments, electric power and pneumatic equipment. The check-out instruments are concentrated in special rooms and bays of the VAB. For the electric power and compressed air supply special dispensing columns are provided in the building. Access of operators to the hatches and joints of the space vehicle during assembly and testing is ensured by means of service units, mobile service platforms, trestles, ladders, etc. The assembled vehicle is conveyed by cranes and cross-arms onto an erector or a transporter-erector trolley.

Concurrently with the launch vehicle, the space body is assembled and tested. If the space centre has a number of maintenance areas for several types of launch vehicles, it is preferable to have a specialized VAB for each type of space bodies. The test equipment for space bodies is supplemented by PRESSURE CHAMBERS for testing space bodies or their components for high-vacuum tightness. An assembled and tested space body is delivered to the PROPELLANT-LOADING STATION of the maintenance area. The amount of propellant loaded into a space body varies from a few kg to several t which calls for different methods of metering; small quantities are weight-metered, while large quantities are dispensed by the volume-metering method. If the volume meters automatically control the density of the propellant, this also ensures weight metering instead of volume metering. When the propellant is measured by volume, the temperature of propellant is carefully recorded, which, knowing the chemical composition of the propellant, makes it possible to determine its density at the moment of loading and thus to convert the units of volume into units of weight. The propellant is fed from the storage reservoir by pump or by pressure. Before loading, the propellants are subjected to thermostatic control and some of them are de-aerated. Air is evacuated from the propellant tanks and a part of the propellant-feed manifolds (up to the membranes) before filling. The compressed gas feed system provides for charging high-pressure cylinders of the

space body and filling the propellant tank ullages with an inert gas, usually helium. The propellant-loading stations are equipped with powerful systems of balanced ventilation and fire-prevention, as well as with sewerage, electric, propellant-loading, and drainage communications and appropriate space-body servicing equipment, such as platforms, trestles, ladders, etc. The station's pipe-lines are equipped with remote-controlled fittings. The loading pipelines have flexible hoses at the ends for joining to the filling necks and connections of the space body. The accomplishment of every operation executed at the propellant-loading station is recorded by a system of sensors and shown by light annunciators and indicators of the remote and automatic control systems. Cryogenic propellants are loaded into the space body on the launch pad. After loading, the space body is conveyed into the VAB where it is mated with the launch vehicle. If the propellant-loading station is situated at a significant distance from the VAB and there is a danger of the propellants acquiring an inadmissible temperature, the transport facilities, whether motor trucks or railway cars, should have some means of thermostatic control. After making sure that the mating of, and the cable connections between, the vehicle and the space body are correct, the fully-assembled space vehicle is conveyed to the launching site.

The *launch complex* is a combination of ground system equipment, buildings with general-purpose technical equipment and specially prepared ground areas with access routes, this complex being intended for conveying the space vehicles to the launch pad, erecting it on the launcher, testing, fuelling, aiming and launching. Some obsolescent launch complexes provide for vertical assembly of the space vehicle on the launcher.

The ground system equipment of the launch complex can be mobile or stationary, which determines the number of buildings on the launch site. The mobile complex is more economical than the stationary one since it requires fewer buildings and, in the event of vehicle explosion on the pad, smaller expenses to compensate for the damage. The difficulties encountered in the realization of the mobile equipment grow with the increase of the size of the launch vehicle and the amount of propellants loaded into its tanks. Special structures of a modern stationary launch complex include: a launcher; a system of lightning rods; a rail track for the mobile service tower or a circular rail track and an under-tower structure for a swivelling service tower; a LAUNCH CONTROL CENTRE; structures with equipment for storage and loading of oxidizer, fuel, and cryogenic propellants into the launch vehicle and for loading the space body (if cryogenic propellants are loaded by mobile facilities, the launch site should have appropriate access routes and covered platforms for the fuellers, ensuring the propellant replenishment up to the moment of launching; if the vehicle and the space body use the same cryogenic propellant, they can be serviced by the same structures and fuelling facilities); a gas supply station and a receiver room; buildings for the neutralization equipment (if the propellant components are toxic) and an evaporating plot for the products of neutralization; a transformer substation and, sometimes, a stand-by Diesel-electric plant; refrigerating plants or a refrigerating centre; water cooling towers and spray ponds; water reservoirs for fire-fighting purposes; sub-surface gangways and passages

connecting the main buildings of the launch complex; a boiler room (some launch complexes draw steam from the boiler rooms of the maintenance area); railway branch lines and hard-surface motor roads and automobile parking lots; administrative and service buildings and fencing. All the buildings are, if possible, hardened against an accidental on-pad explosion of the launch vehicle. Many buildings are vault-like reinforced-concrete structures protected by sand fill. The highest degree of protection is given to the control centre which is either dug into ground or has the shape of a reinforced-concrete earth-mounded hemisphere. The launch complex may have a number of launch pads.

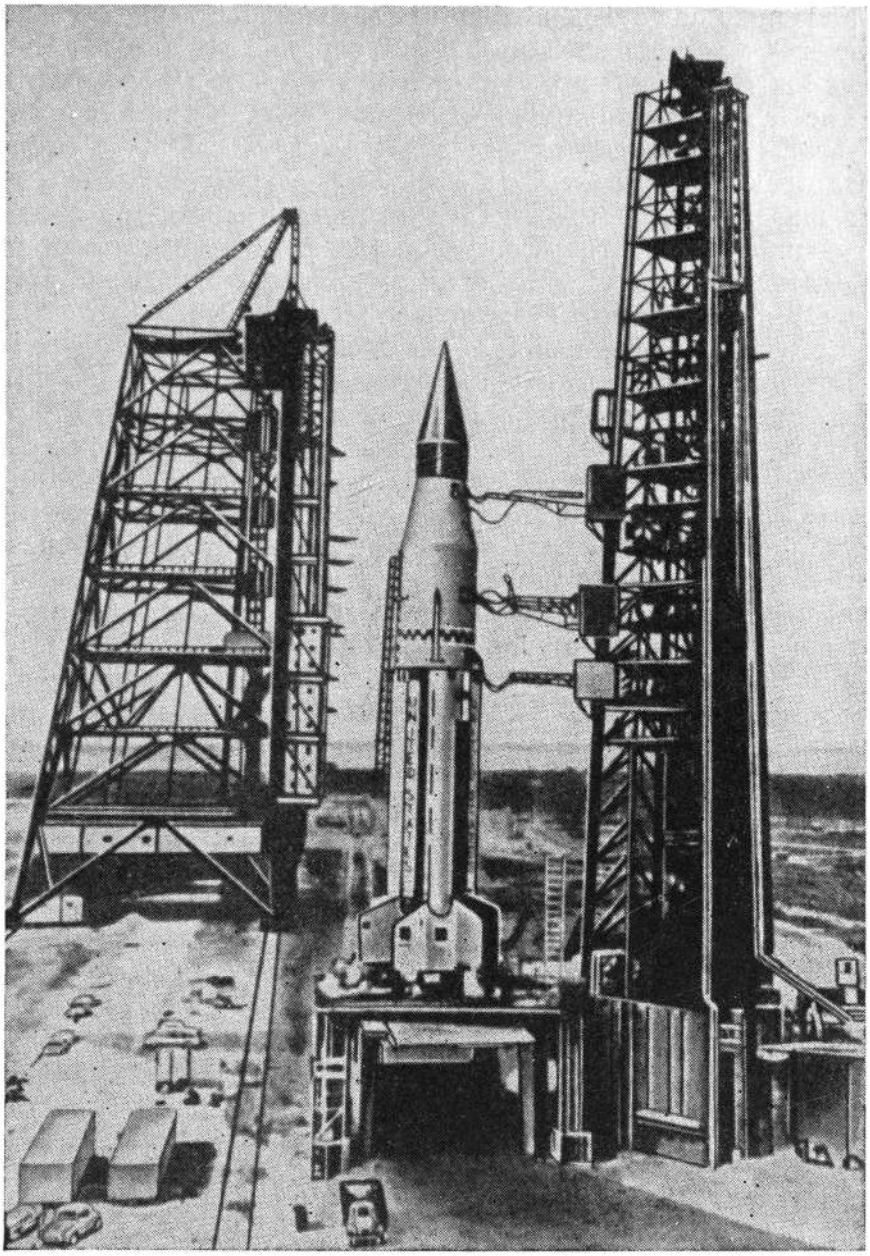
The ground system equipment of the launch complexes for giant space vehicles comprises a transporter-erector vehicle or an ERECTOR and a transporter-erector trolley; a launcher; equipment for servicing the space vehicle on the launcher; equipment for loading the propellant components into the launch vehicle; thermostatic control system; equipment for loading cryogenic propellants into the space body, for charging the space vehicle with compressed gases, and for powering the process equipment; refrigerating and heating plants; air and liquid systems of thermostatic control of the launch vehicle and space body; a system for the neutralization of the spillage and of the remaining quantities of toxic propellant components or their vapours and decontamination of the elements of launch vehicles after draining the toxic propellant components; a space vehicle alignment system; ground electric power equipment; ground parts of the rocket-borne systems of the space vehicle including the level control systems; a space-borne telemetry system, radio control of trajectory measurements, a set of test equipment; an electronic-logical regulator; a LSS; a command radio line for emergency rescue of spacemen; a set of frequency converters; vacuum equipment; a common measurement system of the launch complex; a fire-fighting system; a set of automatic and remote-control systems; a system of remote and automatic control of process operations; sets of launch equipment for the launch vehicle and the space body.

On the launch area the hydraulic jacks of the transporter-erector lift the space vehicle together with the beam to the vertical position so that it is suspended above the launcher. Then mechanisms of the launcher or those of the erector, or both, bring the space vehicle supports in contact with the footings of the launcher; when the weight of the space vehicle is supported by the launcher, the space vehicle is secured by wind-anchoring braces, the beam grabs release the space vehicle, and the beam is lowered to the horizontal position. While being mounted on the launcher, the space vehicle is aligned vertically and, if necessary, in the plane of flight, by means of the guidance system equipment. The gantry-type mobile erectors lift the space vehicle complete with the transporter-erector trolley to the vertical position by means of a system of ropes. The erector gantries are provided with swing-down platforms for the operators to carry out the pre-launch servicing of the space vehicle. Stationary erectors with the platform-like booms are installed near the launcher with the rail-track supporting platform situated at the zero level. The railway transporter-erector trolley is rolled onto the platform and secured there automatically, after which the platform together with the

trolley and the space vehicle is lifted by the hydraulic jacks to the vertical position. The mechanisms lowering the space vehicle on the launcher, as well as the grabs, are, in this case, components of the transporter-erector trolley. Mounting of the space vehicle on the launcher and its vertical alignment are controlled from the system of remote control of the process operations, whose instrumentation and consoles are located mainly at the launch control center. If the space vehicle is delivered to the launch area by a crawler transporter in the vertical position together with the umbilical tower, the tower and the space vehicle are lowered on the launch pad supports by means of the transporter's hydraulic jacks (4 jacks on each of the 4 bogies). After securing the top part, the transporter is additionally lowered by the same jacks and is driven from under the launcher.

The main component of the launch complex is the LAUNCHER intended for the reception, vertical alignment and restraining of the space vehicle in the launching attitude, bringing to it electrical, fuelling, pneumatic, draining, etc. lines, and for the launching proper. Some launchers have devices for azimuth alignment of the space vehicle. Launchers can be either mobile or stationary. The design of stationary launchers is extremely varied, being governed by the design and peculiar features of the launch vehicle. The most complicated design of such systems is evolved for cluster-type longitudinally splitted vehicles which have to be turned together with the launcher for azimuth orientation. In such a case the launcher is sometimes provided with a truss-type bearing structure on which the launch vehicle rests with its supporting elements located in the middle of its height. At launching, these trusses are automatically retracted, thus eliminating the danger of collision with the space vehicle. Stationary launchers are mounted in launch structures which are classified into surface, semihard and hard types. Subsurface launch structures permit reduction of the size and power of the hydraulic erecting system, since the space vehicle centre of gravity is located in this case at a lower height. However, with subsurface launch structures it is more difficult to divert the rocket engine efflux away from the space vehicle and the ground support equipment. Such structures, in addition to flame deflectors, incorporate a system of FLAME CHUTES and one or more exhaust-gas ducts.

Launchers may be equipped with cable masts, propellant-loading towers and umbilical towers, machinery for joining electric and pneumatic couplings and filler and drain connectors. This machinery is actuated for connection and disconnection by electric, hydraulic or pneudraulic drives; disconnection can also be made by the space vehicle motion at the lift-off. Masts and towers can be either collapsible or stationary. Collapsible towers are thrown off automatically by special mechanisms on command from the launch-control console, being directed away from the space vehicle onto shock absorbers to prevent collision with the vehicle and damage to the tower by the engine efflux. Stationary umbilical towers are secured on or near the launcher at a distance guaranteeing against collision with the space vehicle and damaging by hot gases. In such a case they are provided with breakaway supply lines connecting the space vehicle with the corresponding ground pipelines laid on the umbilical tower. Some towers are more than



Launcher with a rocket (USA). Left: the service tower. Right: the umbilical tower.

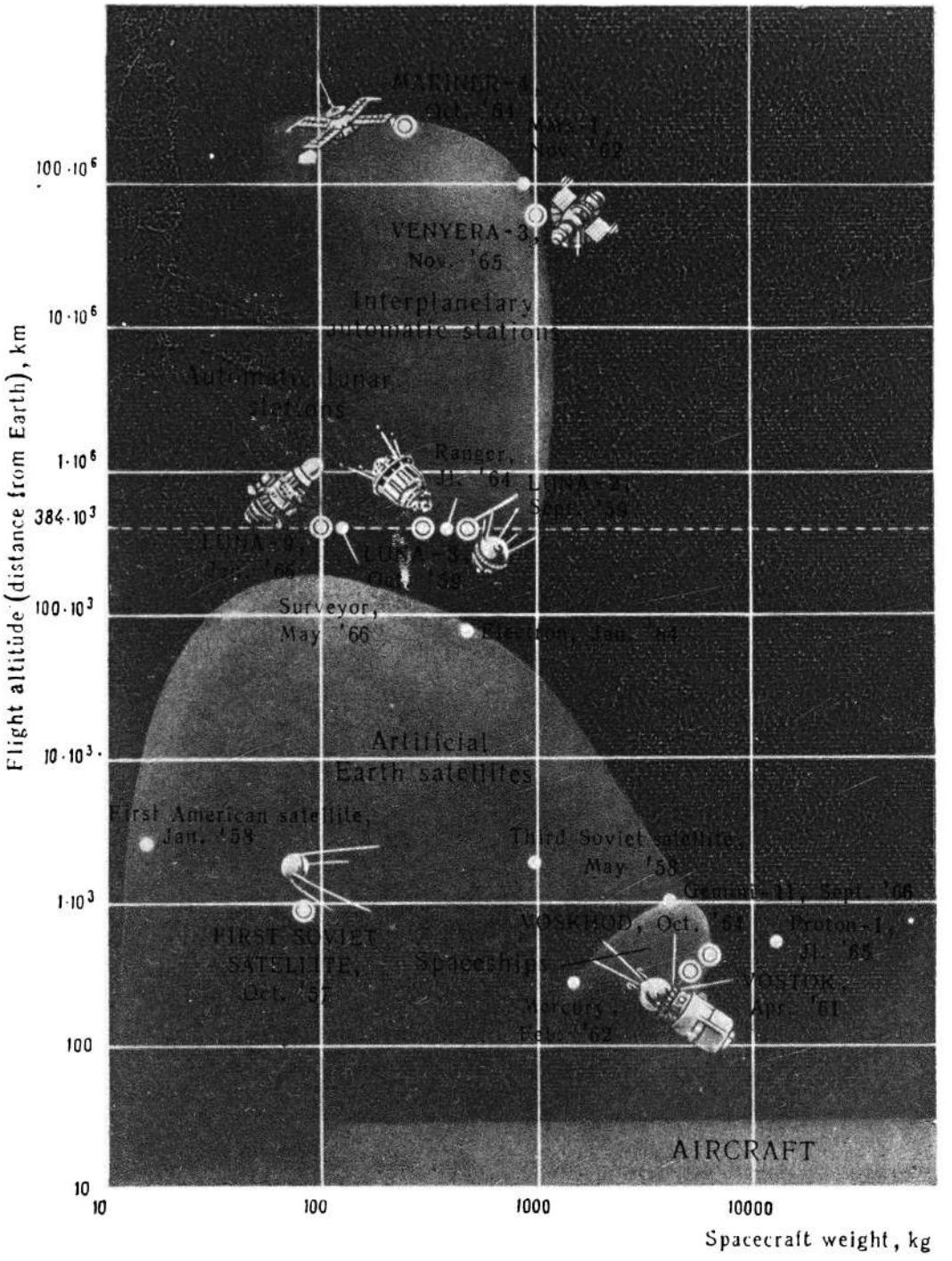
100 m high. The umbilical towers are often used for servicing and are fitted with lifts and swing-down platforms. The launcher uses various servicing mechanisms, such as service towers and trusses, truck-mounted towers, mobile units (based on lift trucks), and special cabins. The units ensure access of operators and delivery of instruments and equipment to various

levels of the vehicle. The towers and trusses can incorporate electric, fuelling, drainage and pneumatic lines with filler connectors, and the piping for loading the space vehicle with propellant components and for thermostatic control. The servicing units are delivered to the space vehicle after its installation on the launcher and are therefore made of the mobile or swivelling type. Self-propelled towers move over rail tracks up to 30 m wide to a distance guaranteeing their safety in case of the space vehicle explosion at launching. The swivelling towers turn around the centre on a circular rail which is an undertower structure. When the azimuth alignment of a space vehicle is achieved by turning its airframe, the service trusses are mounted on the swivelling portion of the launcher and are lowered (turned) from vertical to a horizontal position before the firing. Some mobile service towers travel on the same crawler transporters that carry the erected vehicle to the launch area. The service towers and trusses have retractable, folding and/or stationary platforms with railings, flights of stairs and passenger-and-cargo lifts; sometimes barriers around the platforms create cabins supplied with conditioned air. Some towers are equipped with cranes for assembling the space vehicle on the launcher or for hoisting loads onto the platforms. Large service towers (weight up to 3500 t, height over 100 m) are self-contained units, incorporating a power station, heating, air conditioning, lighting and ventilating systems and a communication service.

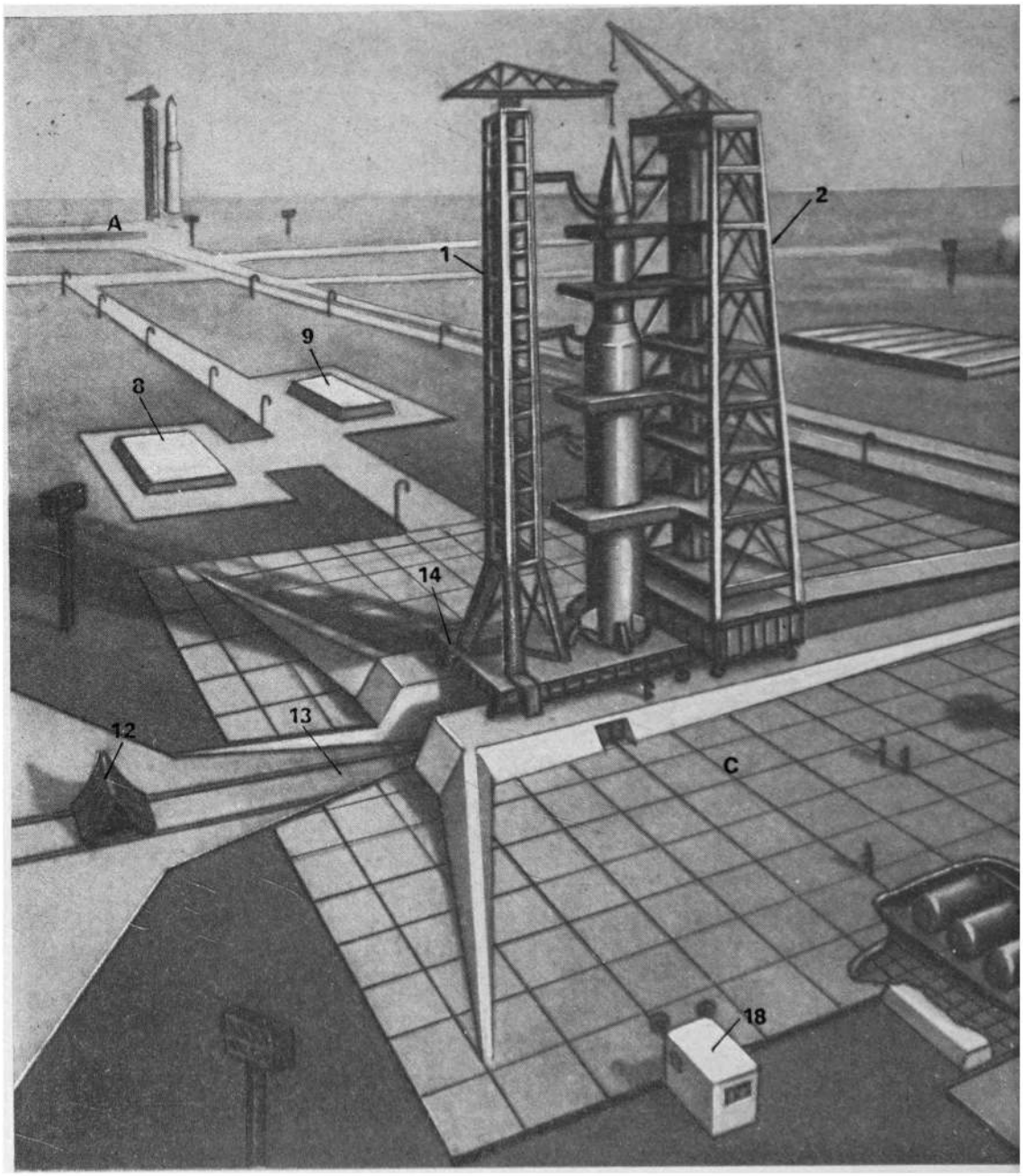
After the space vehicle has been erected and aligned and ground supply lines have been connected to it, launching and check-out equipment and all the ground systems are used to carry out component tests and system integration tests; the results of the tests are recorded by telemetry systems and multi-channel recorders. After interpreting and analyzing the results of the tests, the launch vehicle is loaded with propellants and charged with compressed gases. The propellant-loading equipment includes propellant terminals, pumping plants, drainage containers, and a system of filling and drain lines laid in special subsurface galleries in the launching system, or on the umbilical towers and service trusses. The lines are provided with pipe fittings and groups of hydraulic and pneumatic valves for controlling the fuelling processes, they end with flexible hoses equipped with filling and draining connectors for joining to the launch vehicle. When loading toxic propellant components, the vehicle tanks are closed back to the propellant terminal to prevent the toxic vapour escape into the atmosphere. Besides pump feed, pressure feed of propellants into the vehicle tanks is also employed; this latter method does not call for a heavy expenditure of electric power within a short period of time; however, pressure feed of large amounts of propellant into vehicle tanks situated at a high level calls for huge containers rated for high-pressure, which is not economical. Besides, the pressure-fed system rules out a closed loop connection of the vehicle tanks and the propellant terminal. After pressurized filling, the large propellant-storage reservoirs are filled with high-pressure gas mixed with the propellant vapours, which is particularly objectionable if the propellant is toxic. Therefore, giant launch vehicles in modern launch complexes are fuelled by pump-fed systems. If the launch complex is not equipped with stationary fuelling facilities, use is made of mobile servicers with flexible hoses for connection

Plate I

Spacecraft



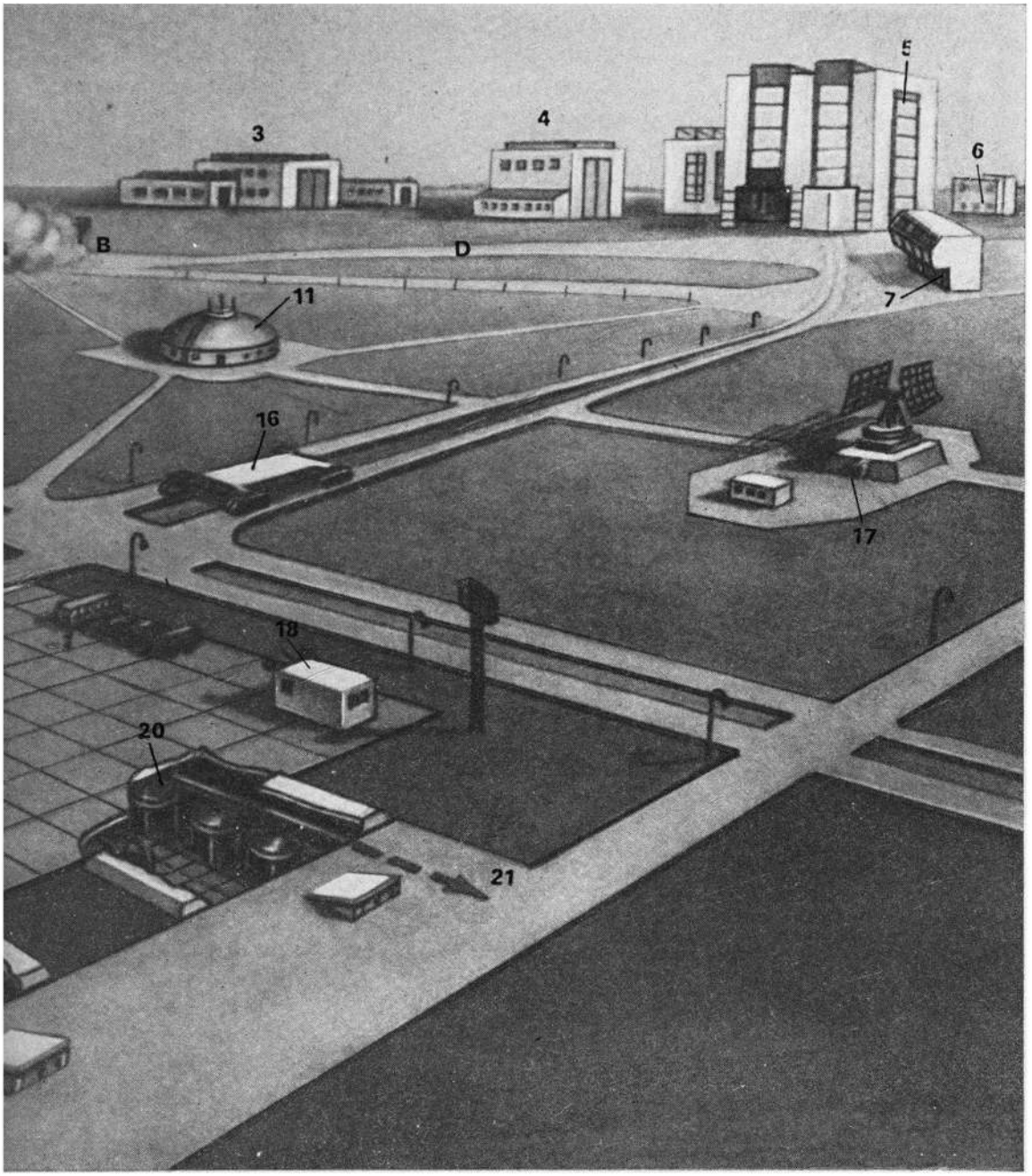
This diagram plotting weight versus flight altitude shows the region of flight of various types of spacecraft: artificial Earth satellites, automatic interplanetary stations, automatic lunar stations, manned spaceships. Large dots correspond to the revolutionary spacecraft whose flights made breakthroughs in the development of space science and exploration. These spacecraft are: the first Soviet Earth satellite *Sputnik-1*, the first automatic interplanetary stations to go to the Moon and Venus (*Luna-2* and *Venyera-2*); *Vostok* and *Voskhod* spaceships that carried the first man into space and the first man to walk out into space; *Luna-3* and *Mariner-4* that took photographs of the Moon and Mars; automatic interplanetary station *Luna-9* which made the first soft landing on the Moon



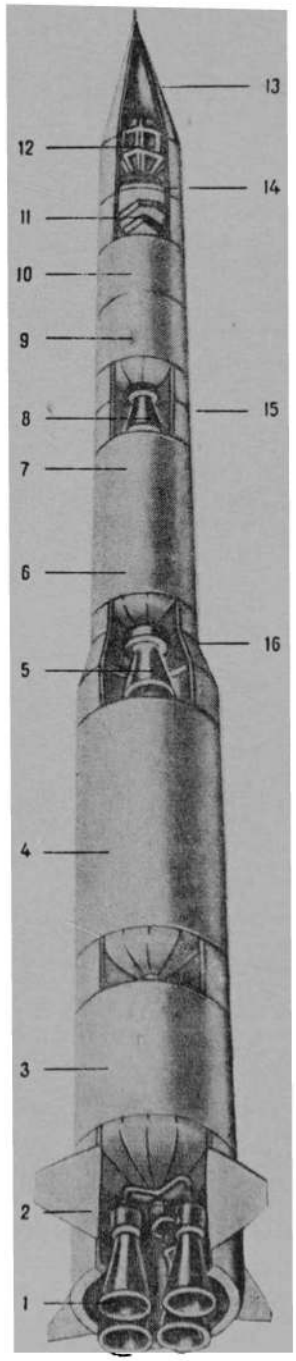
A, *B*, *C* — launching sites; *D* — maintenance area; *1* — umbilical tower; *2* — service tower; *3* — station for loading propellant into space objects; *4* — spacebody assembly building; *5* — vertical assembly building; *6* — compressor plant: *7* — outlying launch control centre; *8* — oxidizer terminal; *9* — receiver room; *10* — fire-

Plate II

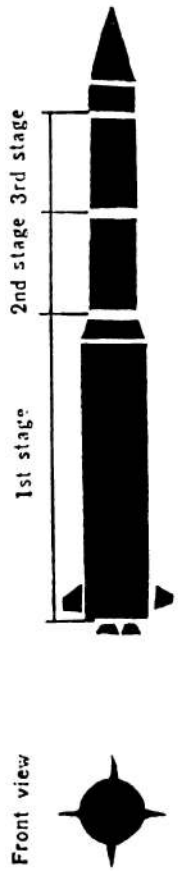
Space centre



fighting water reservoir; *11*—launch control centre; *12*—flame deflector; *13*—exhaust-gas duct; *14*—launcher; *15*—instrument tower for azimuth alignment of rocket; *16*—crawler transporter; *17*—radar station; *18*—crew shelter; *19*—fuel terminal; *20*—hydrogen terminal; *21*—towards evaporation sites



MULTISTAGE ROCKET (3 stages)



1—liquid-propellant engine of 1st stage; *2*—fins; *3*—fuel tank of 1st stage; *4*—oxidizer tank of 1st stage; *5*—liguid-propellant engine of 2nd stage; *6*—fuel tank of 2nd stage; *7*—oxidizer tank of 2nd stage; *8*—liquid-propellant engine of 3rd stage; *9*—fuel tank of 3rd stage; *10*—oxidizer tank of 3rd stage; *11*—control instrument compartment; *12*—payload; *13*—nose cone; *14*—mechanism for jettisonning spacebody; *15*—joint between 2nd and 3rd stages; *16*—joint between 1st and 2nd stages

to the propellant supply lines of the launcher or directly to the launch vehicle. Filters trapping any mechanical impurities from the propellant and ensuring an adequate degree of cleanliness are installed in the delivery pipes as close to the launch vehicle as possible. The propellants are usually metered automatically by means of level control system actuated by level gauges in the launch vehicle tanks. When the pre-established level is reached in the tank, the propellant flow rate is reduced on the command of the level control system and the topping of the tank is completed at this low rate; to promote safety of propellant loading, an emergency level gauge is introduced in the system. On the final command the cut-off valves close and the feed system is rendered inoperative. Sometimes the propellant is metered by flowmeters, or, rarely, by weighing the launch vehicle by transducers built into the launcher. To charge compressed gases into the space vehicle and to power the process equipment, there are a control panel of the receiver room, a control panel of compressed gas supply to the launch vehicle, process system of the launch complex, a gas supply system, the receiver room, and compressed gas network equipped with pipe fittings. The gas supply station may incorporate high pressure air compressors with desiccating units, compressors for gaseous helium delivered to the launch areas in bottles under a standard pressure of 150 at, and liquid nitrogen gasifiers with high pressure plunger pumps. Some gas supply stations have no air compressors and the receivers can be filled through a pipe coming from the compressor plant of the maintenance area or by mobile compressor plants.

To ensure safety, the ground system equipment includes the neutralization and fire-fighting systems of the launch structure. The system of neutralization of vapours and spilled quantities of toxic propellant components consists of a hydraulic system for draining and pumping the spilled propellant into drain reservoirs, neutralization units for the propellant liquid constituents, a drainage system for the propellant vapours and systems for the neutralization or burning of the propellant vapours. The fire-fighting system ensures putting out fires caused by the propellant spillage during fuelling and extinguishing centers of fire after launching or an emergency starting of engines. All of these systems are provided with automatic or remote control.

THERMOSTATIC CONTROL OF PROPELLANT is effected prior to filling the tank, i.e., the propellant components are heated or cooled, whichever necessary. High-boiling propellant components are thermostatically controlled with a view to assure: the permissible difference of temperatures of the oxidizer and the fuel; the maximum or minimum temperatures of the propellants supplied to the rocket engine by the end of the powered-flight phase in summer or winter, respectively, taking into account the heat-exchange processes proceeding in the propellant within the time the fuelled launch vehicle is kept on the launch site and during the powered flight; and the required specific gravity of the propellants. The thermostatic control of a cryogenic propellant consists in its supercooling. Supercooling of cryogenic propellant or re-condensation of its vapours, as well as screen-vacuum or powder-vacuum insulation of the storage containers allow the propellant to be stored for a long time actually without losses. Supercooling continues after fuelling the space vehicle, in fact all the time the loaded vehicle is kept at the launch site.

In this period the heated portion of the propellant is periodically and automatically (in accordance with the sensor readings) drained from the tank into the storage reservoir, supercooled and directed back into the space vehicle tank. In the launch complexes not provided with supercooling facilities, evaporation of cryogenic propellants from the space vehicle tanks is compensated for by automatic feed of additional propellant from a replenisher, the latter being connected with the tanks by the replenish line up to the beginning of launching. The launch vehicle can be charged with all the propellant components and compressed gases simultaneously if these materials do not constitute hypergolic combinations. If, however, such combinations may form, it is recommended to load the propellants one after another to prevent mixing of the inadvertently spilled liquids. On completion of filling, the propellant-loading lines are drained and blown through (in case of toxic constituents) after which the charging and draining connectors are detached. The connector detachment can be either remotely or automatically controlled; manual disconnection is also used. From the beginning of fuelling the fire-fighting system is set in operation; the water for fighting fires, washing off any spilled propellants and setting up water curtains circulates along a closed circuit and can be delivered at any required moment to the distributing header and to the carriage-mounted spouts. The entire pre-fuelling procedure, including the storage of propellants and the fuelling proper, makes use of the system of automatic control of process operations.

Then the servicing units are withdrawn; the service tower or truss is removed from the launcher and the servicing lines laid on the tower or truss are disconnected from the ground lines, these operations being also remote-controlled. All the pre-fuelling and fuelling operations are performed by automatic or remote-controlled systems, thus dispensing with the necessity for the servicing personnel to work in close proximity to the space vehicle. The spacemen board the spaceship after fuelling, from service towers or trusses or from umbilical towers and tl eir lifts. All the prelaunch operations are indicated on the launch console by means of a set of readiness annunciators. As soon as all the systems report their readiness, the firing order is given. The firing key is turned to the "FIRE" position and the "FIRE" button is pushed in to switch on the automatic launch control system. In case of any irregularities or emergency situations, cancellation of commands takes place, and the elements of the launch control system return to their respective initial positions. In case of an abortive launch, the vehicle propellant tanks are emptied, the vehicle is neutralized or decontaminated (if the propellant is toxic), removed from the launcher and taken back to the maintenance area.

The *flight control range* performs the following main functions: trajectory measurements of the space vehicle; transmission of commands to the space body to perform programmes entered in space-borne systems and actuators; transmission of settings, i.e., of the values altering the programmes, to the space body; reception of telemetry information from the launch vehicle and the space body; telephone or telegraph communications with the spacemen through radio channel, and relaying the information; reception and relaying

of TV images from the space body. In addition, the flight control range urgently transmits trajectory measurement data to the integrated mission control centre for determining the orbit or trajectory of the space body.

Information is transmitted by all the possible means of communication. If the analysis of the space body orbit or trajectory indicates the necessity for introducing corrections into the flight programme, the integrated mission control centre supplies the flight control range with the appropriate new settings to be transmitted to the space body. To reduce the volume of information received within one trajectory measuring period from several thousand parameters to a few computed and checked coordinates, the centre should incorporate automatic data-processing lines and computers. This will dispense with the necessity for complicated tracing of distortions which are inevitable in case of urgent transmission of a large volume of information over lines of communication. However, very often, particularly during emergency situations, the centre has but a very short time for computing the orbit or trajectory and making a decision about the setting to be transmitted, this time being insufficient to receive the several thousand measurements again. Besides, it is easier to identify and discard the doubtful data *in situ*. A number of measuring posts one of which is appointed the main measuring post are equipped with practically identical instrumentation including radio-telemetry stations, radio receiving and transmitting sets, powerful antennas, TV sets, automatic data-processing lines and computers, the equipment of the common timing system, means of communication, and sources of electric power and special kinds of current. The posts of the flight control range are situated at a considerable distance from one another to ensure the longest possible spacecraft-to-Earth periods of communication on the largest sections of the orbit or trajectory. All the posts have a common timing system and a reliable communication with the integrated mission control centre, the main post at the space centre, and, sometimes, with one another. If this cannot be achieved by the ground-based posts, the measuring posts are set up on ships which sail out into the oceans beforehand and occupy the required positions. The coordinates of these positions are governed by the type of the orbit or trajectory and the necessity of timely transmitting the commands and settings to the space body. The measuring posts located at the space centre are not necessarily the main ones, since the main post should provide for the communication with the space body on the most vital sections of its trajectory.

SPACE CENTRE WATER RESERVOIR. Serves for accepting and manoeuvring rocket-shipping barges arriving along canals. It is also a reserve stock of water for fire-fighting and cooling down the water of the cooling systems of the condenser of refrigerators, compressors and other installations of the launch complex.

SPACE COMMUNICATIONS. Various systems of space communications are used for transmitting relevant information (telemetry, special measurements, telephone, telegraph and TV), for sending to the spacecraft the command and control signals, and for making trajectory measurements. No space flight is conceivable without some system of communications. Radio communi-

cations are usually resorted to, though in certain cases OPTICAL COMMUNICATIONS have also been used.

Systems of space communications fall into the three following classes: (1) between ground communications stations and an artificial Earth satellite or another spacecraft; (2) between two or more ground stations via some vehicle or other artificial means located in outer space; (3) between spacecraft. The information rate and means of transmission employed differ according to the purpose of the communications line and the type and mission of the spacecraft involved. Thus, there is a great difference between communications lines linking a ground station and a satellite in a low orbit and lines linking a ground station and a distant interplanetary spacecraft. Communications with Earth satellites are characterized by quick changes of the direction of communications, short periods of mutual visibility, relatively small distances and, correspondingly, high levels of signals. Conversely, very weak signals are received from distant spacecraft, but the period of mutual visibility is much greater since the variation of the direction from a ground station to the spacecraft depends mainly on the Earth's diurnal rotation.

Systems of space communications differ basically from systems of ground communication in that the position of the spacecraft changes continuously (and, quite often, very quickly); it is necessary to know the coordinates of the spacecraft at any given moment of time and to direct the receiving and transmitting antennas of the ground station towards it accordingly; the DOPPLER EFFECT causes continuous variation in the frequency of the signals received; the zones of mutual visibility of the ground station and spacecraft are limited and change with time; the spacecraft transmitters have a low emissive power; the received signals are very weak, as they have to cover great distances. All these specific features of space communications call for the employment of special equipment, such as large-size track antennas, low-noise receivers, highly efficient systems for detecting, separating and recording the signals. In order to know the position of the spacecraft at any given moment, it is necessary to measure its coordinates periodically and compute its trajectory parameters. Thus, it is evident that reliable space communications can be maintained only by joint operation of the system of trajectory measuring instruments, the computer centre and the system of spacecraft control. Depending on their direction and function, various wavebands are used for the space communications channels. The distribution of frequencies and the sequence of their utilization is determined by RADIO COMMUNICATION REGULATION.

Earth-spacecraft communication. Communication between a ground station and a spacecraft is maintained for two-way transmission of all forms of required information. The Earth-to-spacecraft (E—S) and spacecraft-to-Earth (S—E) communication lines have a different information content and capacity. The E—S line serves for transmitting control commands and trajectory measurement signals to the spacecraft and, in the case of a manned spacecraft, for radiotelephone, radiotelegraph and TV communication with the crew. The S—E line is used for monitoring, trajectory measurements, transmission of telemetry data and purposeful information (e.g., meteoro-

logical, scientific, navigational or other, depending on the mission of the spacecraft) and, for communication of the crew of a manned spaceship with the Earth. As a general rule, the S—E line has a much lower capacity, since the emissive power of the space-borne transmitter is less than that of the ground station transmitter used for the E—S line (the power of a space-borne transmitter is usually several W or tens of W, whereas the ground station transmitter generates several kW or tens of kW). Nevertheless, the main flow of information is carried by the S—E line. This necessitates the use of ground station antennas having a great effective area (several tens of m^2) for reliable reception of information sent by the spacecraft. In cases when information is sent by interplanetary spacecraft, the effective area of the receiving antennas equals hundreds and thousands of m^2 as the signal diminishes in proportion to the square of the distance. Only exceptional and very expensive antenna systems have an effective area of 2000—5000 m^2. Such antennas are capable of maintaining radiotelephone communication over distances as great as those to Venus or Mars.

Radio communication with man in space came into being on April 12, 1961, when Pilot-Cosmonaut Yu. A. Gagarin orbited the Earth in the *Vostok* spaceship for the first time in the history of mankind. Reliable two-way radiotelephone and radiotelegraph communication with Earth in the short-wave and VHF bands was maintained throughout the entire flight. Subsequent flights of the *Vostok* and *Voskhod* spaceships demonstrated further improvement in radio communication with the Earth; communication between spaceships was tested with success during group flights. On August 1961 the picture of Pilot-Cosmonaut G. S. Titov was transmitted to Earth for the first time, during his flight in the *Vostok-2* spaceship. A space-borne tape recorder was employed for speech recording and automatic accelerated reading of records by commands from the Earth when the spaceship approached a ground station of radio communications. The number of TV images transmitted per second was reduced to ten in order to narrow the frequency band. Birth was given to Soviet SPACEVISION in August, 1962, during the group flight of Pilots-Cosmonauts A. G. Nikolayev and P. R. Popovich. Spacevision became firmly established in the practice of later space flights and allowed TV spectators to witness the flight of the multi-seater *Voskhod* spaceships and the extravehicular activity of Pilot-Cosmonaut A. A. Leonov.

The longest-range two-way radio communication is practised in flights of automatic interplanetary stations to other planets. Thus, radio communication with *Mars-1* on Mars mission in 1962 was maintained until the spacecraft reached the distance of 106,000,000 km. *Venyera-4*, *-5* and *-6* (1967, 1969) maintained radio contact with the Earth throughout their flight to Venus and atmospheric entry. Radio contact with *Mariner-4* was regular throughout its flight to Mars.

Mariner-4, which had taken photos of Mars, began transmitting the pictures when at a distance of 215,000,000 km from the Earth. When *Mariner-4* reapproached the Earth in 1967, radio contact was established at a distance of 346,000,000 km.

Communication via artificial earth satellites. Radio communication over great distances is usually achieved by the employment of line-of-sight relay

lines made up of two terminal stations and several intermediate relaying points (repeaters). The spacing of the repeaters along the line depends upon the distance at which they remain in sight of each other and, in the case of ground-based repeaters, is practically never greater than 50 to 70 km. Installation of a repeater on board a satellite orbiting at a high altitude ensures efficient radio communication between ground-based points located several thou. km apart. Communication satellites can be used for establishing both individual communication lines and networks of radio relay lines, thus enabling the relaying of TV programmes and multi-channel radiotelephone and radiotelegraph messages. Such communication can be maintained by satellites having various orbits and circulating at different altitudes. Communication satellites are sent into circular stationary (see STATIONARY EARTH SATELLITE), greatly elongated elliptic synchronous (see SYNCHRONOUS SATELLITE WITH ELLIPTIC ORBIT), medium-altitude circular and low-altitude circular orbits.

Stationary satellites hover permanently above a given point on the Equator and are capable of maintaining a round-the-clock radio communication between ground-based stations located at latitudes lower than 75° within a radius of up to 8000 km from the point above which the satellite is located. Three such satellites situated at equal distances from each other along the Equator enable man to maintain regular communication between any ground stations located on the mentioned latitudes. Greatly elongated elliptic synchronous orbits having an apogee directly above the centre of the serviced line of communication and a period of revolution equal to 12 or 24 h are very convenient, since, on proper selection of the inclination and apogee of the orbit, the satellite remains in sight for a greater part of the day. Such orbits are the most advantageous for communication at latitudes higher than 70°—75°. Large ground-based antennas have to be used when dealing with communication satellites put in a stationary or elliptic synchronous orbit, as the distance between the satellite and the ground station is greater than 30,000 km and the signals received are rather weak. Communication satellites sent into medium- or low-altitude circular orbits provide a higher level of the received signals. However, it is to be noted that lowering of the orbit altitude shortens the period of mutual visibility of the satellite and ground station, reduces the visible region and, as a result, calls for a considerable increase in the number of satellites needed to maintain continuous communication. Besides that, the tracking and guidance systems of ground-based antennas become much more complicated. Direct communication between distant points is practically impossible in the case of low-altitude orbits and it becomes necessary to employ a system of RADIO RELAY LINE WITH DELAYED RELAYING. But the signals received by ground stations are sufficiently powerful and the employment of large and expensive antennas becomes unnecessary. This permits the use of small mobile stations for communication via low-altitude satellites.

Communication satellites may be equipped with an ACTIVE RELAY STATION (repeater) capable of amplifying the re-transmitted signals or, alternatively, with a PASSIVE RELAY STATION (reflector). A passive relay station can service a network of a great number of radio lines operating at different fre-

quencies, since it reflects or dissipates the energy of many simultaneously incoming radio signals without any mutual interference. An active relay station can service a communication system having a limited number of lines, mutual interference of the radio signals being prevented by frequency, time or code division of the channels, by maintaining the signals at a specified level and by avoiding overload of the repeater. Besides communication satellites with a passive relay station in the form of a reflector, communication systems making use of widely spread reflectors, such as a BAND OF NEEDLES or a CLOUD OF IONIZED PARTICLES, have been proposed and tested.

When using a reflector, the required level of the received signal is obtained either by considerably increasing the generating power of the ground-based transmitters, or by narrowing the frequency pass-band and slowing down the rate of transmission of the messages. The economical efficiency of communication is improved by the employment of multi-channel radio communication lines and stepping up the rate of transmission of the messages, but this necessitates broadening of the frequency pass-band of the communication line. A wide pass-band is also required for adequate relaying of TV programmes. Broadening of the pass-band, however, increases the risk of distortion of the received messages by radio interference, as rather weak signals are received. Therefore, the provision of conditions under which messages are received at a permissible level of distortion is a major problem which is solved by the emission of more powerful radio signals, proper selection of radio communication frequencies, reduction of the level of RADIO RECEIVER NOISE, employment of efficient coding, adoption of a suitable method of modulation, reception and processing of radio signals at a low signal-to-noise ratio, etc. Thus, the frequencies of radio signals are selected within a range from 1 to 10 Gc/s, since interference due to COSMIC NOISE increases sharply at lower frequencies, while interference caused by ATMOSPHERIC NOISE is most manifest at higher frequencies; noiseless maser or parametric amplifiers cooled by liquid helium are used in the first stages of amplification of ground station receivers.

The power of radio signals supplied to the input of the ground station receiver increases with the dimensions of the receiving antenna and the radiating power and dimensions of the transmitting antenna of the repeater. In the case of a system of communication employing a passive relay station, this is attained by increasing the radiating power and dimensions of the ground station antenna, the dimensions of the relay station reflector, or by the employment of relay stations providing a directed emission of energy towards the ground station. These measures have their limitations, as they increase the investment and operation cost of the communication system.

Communication between spacecraft. Communication between spacecraft is required for the exchange of information between the crews of two or more spaceships in outer space. This is also applied to communication between the crew and spacemen on space walk. Besides, communication may be established between two automatic spacecraft for re-transmitting signals, making trajectory and navigational measurements, and controlling the motion and approach of the spacecraft.

Communication between spacecraft has certain peculiarities. It is usually established between interacting spacecraft and thus covers short distances. Omni-directional communication is preferable owing to the difficulty of mutual orientation of the spacecraft antennas. Any suitable wave-band can be adopted for communication, as there is no atmospheric or, at high altitudes, ionospheric interference. The possibility of interference by powerful ground stations should be taken into account when selecting the wave-band and planning the system of intersatellite communication. Systems of space communication may become even more complicated in the future with the advent of landing expeditions on the Moon or other celestial bodies, since this will make it necessary to maintain reliable communication both with the spaceship remaining in the circumplanetary orbit and with the Earth. A system of transmission of regular TV programmes via special Earth satellites for direct reception by ordinary TV receivers is planned for the near future. This will permit to introduce TV throughout the world and to transmit central TV programmes to any point of the globe. The invention of laser opens good prospects for optical communication, since optical waves can be used for simultaneous transmission of thousands and tens of thousands of messages by a narrow beam (having a divergence of not more than a few angular seconds) over tremendous distances (up to several tens of light years) at a relatively small size and low input of the transmitter. However, the narrowness of the emitted beam and reception of optical waves call for thorough stabilization of the devices and orientation of the optical system in the direction of the spacecraft and make it very difficult to establish and maintain communication. It is most expedient to employ a system of optical communication between spacecraft beyond the Earth's atmosphere, as the latter absorbs and dissipates a considerable percentage of the energy of optical waves.

SPACECRAFT. Vehicles intended for flight up to or in space, e. g., launch vehicles, space rockets, spaceships, automatic and manned stations (orbital or interplanetary), artificial satellites of celestial bodies, aerospace planes. Spacecraft is a general term that embraces the various types of such vehicles, including those powered by means other than rockets (e.g., SOLAR SAIL, etc.). A feature common to most spacecraft is sustained operability in space flight. This is attained by maintaining fixed thermal conditions within the spacecraft, providing power supply to space-borne equipment, establishing radio communication with the Earth, etc. In the sealed cabin of a manned spaceship the atmosphere suitable for breathing and a supply of food and water must be available for the crew.

The flight of a spacecraft may be divided into two phases: launching, during which the necessary speed and direction are imparted to the spacecraft, and the orbital phase, during which the spacecraft mainly coasts according to the laws of celestial mechanics. In many cases spacecraft are fitted with rocket engines for mid-course correction or deceleration for landing. The powered flight path (launching, mid-course correction, deceleration) is much smaller than the orbital flight path. An exception are spacecraft powered by electric rocket engines which operate over a greater part of the flight path.

A rocket is the only means of space flight. Basically the rocket flies by pushing against the mass of jet efflux flowing from the rocket's engines and produced by burning the propellant carried by the very rocket. Therefore as distinct from other flying vehicles, it does not need a surrounding medium to support its motion. The principal power and performance characteristics of a rocket are primarily determined by the engine and the type of propellant used. The velocity of gas ejection from the engine nozzle and the engine's thrust are of prime importance in establishing the power capacity of the rocket. At a given velocity of jet flow, determined by the type of propellant used and the engine efficiency, the maximum speed of the rocket will depend only on the ratio of the propellant weight to the total (launching) weight of the rocket. Using modern chemical propellants, the jet can attain velocity of 3000—4000 m/s. At these velocities a single-stage rocket is practically unable to reach the speed required for space flight (over 8 km/s). To attain this speed with a single-stage rocket, propellant must constitute 93—96% of its total weight, while the weight of the airframe and payload would accordingly have to amount to 7—4% of the weight. It is impossible to construct a rocket of such light weight that would include the airframe, the powerplant and the control equipment. The rocket's performance can be greatly improved by applying the principle of separation in flight of those parts of the rocket, which have exhausted propellant stored in them. This principle is utilized in composite or MULTI-STAGE ROCKETS.

The rockets employed in space flight are called LAUNCH VEHICLES and SPACE ROCKETS and generally have from 2 to 4 stages. The design of these rockets is very diversified. Space rockets have an extremely light-weight structure which together with the powerplant accounts for no more than 10—12% of the weight of the propellant. Design of such structures that will possess high strength and adequate rigidity is a highly complex engineering problem. Apart from utilizing alloys of high strength/weight ratio, original design concepts are a necessity for attaining light-weight structures. For example, INTEGRAL TANKS are simultaneously structural members of the airframe. By creating a certain pressure within the tanks, their shell can be maintained in tensile conditions which are most favourable for thin-shell structures. Hence, it is possible to create thin-walled propellant tanks of large volume that have high strength and rigidity and the ability to withstand the compressive and bending stresses experienced by the rocket airframe in flight. The rocket structure is highly stressed, a circumstance that necessitates complete utilization of the strength of the materials and perfect design of structural units for airframes of considerable size. Besides being statically stressed, the structure is subject to dynamic loading, including vibrational loads produced mainly by the rocket engines. All this requires utmost care at every phase of design, detailed knowledge of all the forces that come into play during flight, and thorough study of the dynamic behaviour of the structure with the aid of the most modern methods of investigation. Each rocket includes a number of systems and units whose functions are to control flight, to separate the stages, to pressurize the propellant tanks, and to control the flow rates of propellant components to the engines. The FLIGHT CONTROL system keeps the rocket on the pre-determined trajectory,

stabilizes it in respect to the centre of mass, controls the rocket engine (thrust adjustment, engine starting and cut-off), and sends out the stage separation commands.

The powerplant of space rockets consists, as a rule, of several rocket engines whose operation is synchronized by the control system. In this way the total thrust values are brought up to hundreds and thousands of t. Thus, the launch vehicle of the Soviet *Voskhod* spaceship had 7 rocket engines which developed a maximum total thrust of 650 t. ROCKET ENGINES and their individual sub-assemblies have very high power/weight ratios and are far superior to other types of engines. The weight/thrust ratio for rocket engines is less than 10 kg/t for powerful engines and 10 to 25 kg/t for medium- and low-power rocket engines. The TURBOPUMP UNIT that delivers the propellant into the engine's combustion chambers is capable of tens of thousands of hp and has a weight ratio of not more than several tens of g per 1 hp. As regards power and weight characteristics, intricacy of design and level of performance of system and sub-systems, space rockets are one of the most stupendous achievements of modern science and engineering.

A distinctive feature of most spacecraft, present and future, is that they are designed for sustained independent functioning in outer space. In many respects (the laws of motion, thermal conditions, etc.) spacecraft can be considered an independent celestial body and, moreover, one on which definite environment is maintained for equipment operation and human life support. For this purpose spacecraft must include systems to maintain definite temperature conditions, to energize the equipment, and to establish radio communication with ground stations. In a manned spaceship the atmosphere in the SEALED CABIN must be maintained suitable for breathing; the crew must be provided with adequate food and water for the entire flight. Spacecraft are practically always designed for definite missions (scientific investigation, radio relay, etc.) and therefore carry the appropriate equipment. In many cases they have systems for ORIENTATION and SPACE NAVIGATION, as well as vernier engines that correct the flight path.

The equipment of the spacecraft includes the following systems: thermal control, electric power supply, radio communication and telemetry, orientation and flight control, landing, and a LIFE SUPPORT SYSTEM. All of these systems are usually combined by a common electrical control and power supply circuits which operate and interconnect them. Some types of spacecraft may or may not include certain systems. Thus, automatic space stations have no need for an LSS, spacecraft not requiring orientation have no orientation and attitude control systems, etc. The most intricate spacecraft, i.e., manned spaceships, are equipped with all the systems.

Maintenance of the required temperature in a sealed capsule by a TEMPERATURE CONTROL SYSTEM is a complex engineering problem. As distinct from conditions on the Earth, only radiative heat transfer is possible between two bodies in space. A spacecraft in flight receives heat from external sources, primarily from the Sun, the Earth and other celestial body nearest to the spacecraft. The spacecraft, in turn, must radiate heat into the environment, the rates of radiation being the function of the aggregate heat absorbed from external sources and produced by equipment operation and vital

activity of the crew. This process of heat absorption and radiation requires balancing, otherwise the temperature within the spacecraft may exceed the permissible limit. Regulation of the gross heat balance by heat exchange of the spacecraft with the environment is usually attained by providing the spacecraft with radiating surfaces. These may comprise part of its skin or be separate radiators. The radiating surfaces are given a special finish to impart optical properties which ensure that they radiate much more heat than they can absorb from external sources. By transferring the heat gained within the spacecraft at one or another rate, the heat balance may be adjusted to change the temperature in the spacecraft as required.

A specific feature of the heat processes inside the sealed cabins and compartments of a spacecraft is that there is no heat transfer by convection because of weightlessness in flight. This hinders heat transfer between the various parts within the spacecraft and it takes place, primarily, due to airframe conductivity. Hence, one of the vital tasks of the temperature control system is to maintain a definite temperature level in the spacecraft, i.e., remove the heat at its source (in certain units), equalize gas temperature in the modules, and to maintain the specified local temperature conditions required by various elements of the structure and equipment. This task is fulfilled by means of forced, sometimes guided, gas circulation in the sealed compartments or by liquid heat carriers circulated through the so-called liquid circuit of the temperature control system. Heat is taken up by the liquid carrier passed through gas-liquid heat exchangers arranged within the modules or by circulating the liquid directly through the heat-producing pieces of equipment or their elements. Modern temperature control systems are capable of maintaining the temperature in the spacecraft within very close limits despite the variation in heat inflow from external sources (passage into the shadow of the Earth, flight at changing distances from the Sun), and sharp changes in the rate of heat gain within the spacecraft on cut-in or cut-out of space-borne equipment.

A vital problem in space flight is the electric power supply for the space-borne equipment. The simplest solution is to supply the power from a set of storage batteries charged prior to launching. However, their use is only applicable for short-time flights lasting not more than 1 or 2 weeks. Modern storage batteries have a capacity of about 100 Wh/kg of weight. But in some cases, a spaceship or heavy Earth satellite may have an average power requirement amounting to hundreds of W, and a month-long flight would perhaps require a storage battery weighing a number of tons. The several directions of attack that may be used to solve the electric power supply problem are:

(1) Development of power sources with better watthour-to-weight ratios than obtainable with conventional storage batteries, e.g., FUEL CELLS which produce electric energy through electrochemical reaction of two substances (e.g., oxygen and hydrogen). Fuel cells with supply of working substances have a watthour-to-weight ratio 4—5 times that of a chemical storage battery. They are already beginning to find application in the power supply systems of certain spaceships (e.g., *Gemini*).

(2) Development of SOLAR BATTERIES which convert solar radiation into electric power. This source of power is widely used on the latest of the un-

oriented and oriented spacecraft. The former have solar batteries consisting of several panels arranged so that at least one of the panels faces the Sun regardless of the attitude of the spacecraft.

(3) Development of nuclear power sources (reactor and nuclear-isotope batteries). Nuclear power units incorporating a reactor are, in effect, equivalent to a miniature nuclear electric power station designed for operation in space environment. Work is in progress on the development of units with outputs of up to several kW. In future we may expect the appearance of nuclear power units with outputs amounting to thousands of kW to energize electrically powered spaceships designed for flight between the orbits of planet satellites. Nuclear-isotope batteries, wherein radioactive decay of isotopes evolves heat for conversion into electric energy, usually develop an output ranging from tens to hundreds of W.

Flight of automatic spacecraft and manned spaceship is inconceivable without means of radio communication with the Earth. Transmission of telemetry and TV signals to the Earth, reception of radio commands from the Earth, trajectory measurements, and telephone and telegraph communication between the spacemen and ground stations are the main functions of the spacecraft radio equipment (see SPACE COMMUNICATIONS).

Many of the newest space vehicles, primarily manned spaceships, are equipped with rocket engines to correct their orbit and to decelerate them for landing on the Earth or another celestial body. Such spacecraft carry systems for orientation and flight control. Many spacecraft have no engines, but are provided with an orientation system because their attitude in space must be controlled in order to achieve the mission goal, such as observation of the cloud pattern over the Earth, study of the Sun, etc.

All the equipment on board the spacecraft is designated for operation on a pre-determined programme. Some of the elements of this programme can be set prior to launching, but the larger portion of the programme is established directly in flight, taking into account deviation of the actual trajectory from the design path, changes in the condition of the equipment, and other factors. Therefore control of space-borne equipment by radio command from a ground station is provided. The volume of this command information depends on the complexity of the spacecraft and its mission. Besides direct transmission of commands from the Earth, the spacecraft systems are often controlled by a space-borne programme timers designed to deliver the necessary commands in a specified sequence and at present time. The timer programme can be set prior to launching or transmitted during the flight. The programme timers serve to control the spacecraft equipment during intervals when there is no radio communication with the Earth, between communication sessions and when a series of interrelated commands must be transmitted within a limited length of time, e.g., during landing.

On manned missions, the crew can control the spaceship equipment and flight. Manual controls (handles and buttons) and system operation instruments are usually arranged within the cabin on the spaceman's cockpit. The flights of Soviet and American spacemen have confirmed that man is capable of controlling a spaceship.

Spacecraft landing on the surface of the Earth or another planet is one of the most difficult problems involved in interplanetary flight. A spacecraft travels relative to the Earth or another celestial body at a speed equal to or greater than the first cosmic velocity. For landing, this relative velocity must, by some means, be reduced to zero by the time of touch-down. Two methods, different in principle, may be used. The first is to employ reactive braking forces, the second is to make use of aerodynamic forces arising in flight through the atmosphere. If the first method is used, the spacecraft or its landing module must be equipped with a retro-rocket and supplied with propellant. However, the weight of the retro-rocket is much larger than that of the landing module. For this reason retro-rockets are to be used only for landing on a celestial body devoid of an atmosphere, e.g., the Moon. Descent with aerodynamic braking, more efficient from the point of view of weight, is the main method used for landing on the Earth. Usually, the only part of the spacecraft landed is the re-entry body accommodating the crew and part of the systems. The modules of the spacecraft carrying the equipment for orbital flight are separated from the re-entry body at the beginning of the re-entry trajectory. In the majority of cases, the re-entry body is actually the sealed cabin in which the crew remains throughout the flight. During re-entry, the capsule travels along a sloping trajectory and is gradually decelerated. This makes it possible to avoid excessive *g*-loading. On a ballistic trajectory the loads may reach 8—10 g, while in descent on a glide trajectory, when both aerodynamic drag and aerodynamic lift forces are experienced, the *g*-loading can be reduced by a factor of 1.5—2. During re-entry, the skin of the capsule is subject to intense AERODYNAMIC HEATING and can reach a temperature in excess of 6000°C. Therefore the capsule is provided with a heat-protective coating consisting of materials with high heat resistance and low heat conductivity. Flight through the atmosphere causes ablation, i.e. a process during which the outermost layers of the coating on the nose portion of the re-entry body are fused and evaporated and carried away by the air stream. The heat is thus partly extracted and its transfer through the skin prevented. In the terminal phase of the descent trajectory, when the height is only several km, the velocity drops to 150—250 m/s. Further deceleration before landing is usually attained with the aid of a parachute system. On the *Voskhod* and *Soyuz* spaceships, use was made of a soft-landing system which permitted the touch-down speed to be reduced to practically zero.

Spacecraft structures have many distinctive features to meet the specific environment of space: high vacuum, meteoric collisions, intense radiation, and weightlessness. In high vacuum, frictional processes acquire new properties, and phenomenon known as cold welding occurs. Conventional mechanisms are incapable of operating reliably in such conditions. In this connection various mechanical devices arranged outside the sealed units have peculiar design features: special materials, sealing of certain units, etc. Certain outer structural elements may be influenced by meteoric particles moving at velocities of 20—70 km/s. The smaller meteoric particles gradually destroy the external surfaces of spacecraft. This meteoric erosion during prolonged flight may change the optical characteristics of observation win-

dows and optical devices, spoil the surfaces of the temperature control radiators and solar cells and thus disturb the heat balance and electric power supply system. This means that the surface of many elements of spacecraft must have coatings that are highly resistant to meteoric erosion. The larger meteoric particles may pierce the skin of the spacecraft and depressurize it. The probability of puncture is slight for small spacecraft on relatively short flights and does not require any special measures of protection. However, for large spaceships intended for prolonged flights, the risk becomes so great that their design must make provisions for protection against meteors. Intense radiation (fluxes of charged particles in the Earth's radiation belt and during solar flares) may also be detrimental to certain elements of spacecraft. The most sensitive to radiation are the solar cells, semi-conductor devices, and parts constructed of organic materials. To combat this danger, the solar cells and other elements are sometimes provided with a suitable coating.

A very significant role in space-rocket engineering is played by reliability. High reliability is important for all types of spacecraft, but it is particularly important for manned spaceships. A wide range of measures is taken to ensure reliability in all stages of creation and preparation for launching of space vehicles. Among these measures are: development of high reliability of component parts and equipment; strict quality control at all stages of manufacture; simulation of space flight conditions to check the operation of the various systems and hardware; integrated pre-launch tests, etc. Besides this, higher reliability of spacecraft is attained by duplication, triplication, and redundancy of certain systems and instruments and by application of automatic circuits for debugging a unit or one of its components.

The first years of space-system engineering have seen the development of spaceships for manned flights in near-Earth space, automatic spacecraft for deep-space missions, for soft landings and surface missions on the Moon, and Earth satellites for scientific research and such practical purposes as communication, navigation and meteorology. Real possibilities now exist for the development of new types of spacecraft such as MANNED ORBITAL STATIONS, rocket-space systems for LUNAR EXPEDITIONS, heavy manned interplanetary spaceships for flights to Mars and Venus, and automatic spacecraft for scientific missions to Jupiter, Saturn and other outer planets of the solar system. The flight weight of such space vehicles will be tens and hundreds of tons, and the duration of flight in some cases will be several years.

SPACECRAFT ALTIMETER. An instrument for periodic or continuous measurement of the distance separating the spacecraft from the surface of the celestial body in whose proximity the spacecraft moves. When making a soft landing on a planet or a satellite with no surrounding atmosphere, the signals supplied by the altimeter are employed to control operation of retro-rockets; in artificial satellite altimeter readings are used to compute certain parameters of the orbit. Operation of the most common type of spacecraft altimeters is based on radar tracking of the surface of the planet or other celestial body.

SPACECRAFT AXES. Three mutually perpendicular imaginary lines that intersect at the spacecraft centre of mass and are associated with its air-

frame. Owing to the great variety of outer shapes of spacecraft, their axes have no firmly established names similar to those adopted for aircraft (e.g., longitudinal axis or transversal axis). Only the axes of satellites having an ORBITAL ORIENTATION are designated according to the angular coordinates adopted for such satellites (PITCH, YAW, ROLL axes).

SPACECRAFT SYSTEM OF RADIO COMMUNICATIONS. A set of radio equipment installed on board the spaceship for providing regular communications of the crew with the Earth and, during group flights, between the spaceships. Radiotelegraph and radiotelephone communications during low orbital flights can be maintained in the HF and VHF bands whereas during flight above the ionosphere only VHF and SHF bands can be used. The speech of the spacemen can be tape-recorded and then transmitted to the Earth at a high speed. A separate radio receiver may serve for receiving radio broadcast programmes. TV pictures of the crew on board the spaceship can be transmitted to the Earth in the VHF and SHF bands (see SPACEVISION). The radio equipment of the communications system usually employs semiconductors. The SHF band with directional transmission should be used during distant space flights. Optical communications are also feasible.

SPACE FARM (greenhouse). A part or compartment of a spaceship where higher plants are cultivated. The optimum conditions for planting, growth, development, and crop harvesting are ensured by devices for light distribution, air conditioning, preparation, distribution and delivery of nutrients, removal of TRANSPIRATION MOISTURE, etc. The space farm should grow the planned amounts of higher plant BIOMASS, this being facilitated by preselection of species and numerical composition of the higher plant POPULATION.

SPACE FLIGHT IN LEGENDS AND FICTION. From time immemorial the dreams of man to fly freely into skies and travel to distant heavenly bodies have been widely reflected in the folklore and fiction of many nations. Stories about such flights span as far back as the Assyro-Babylonian epics, and to ancient Chinese and Iranian legends. The ancient Hindu epic, the *Mahabharata*, contains instructions for flight to the Moon. Rama's flight in the heavens is described by the Hindu poet Tulsi Das in the epic *Ramayana* (1575). From Greek mythology we know about the fatal attempt of Icarus to fly to the Sun with wings secured by wax. According to one legend, Alexander the Great attempted a flight into the skies on griffons. A version of this legend was written later by the Tajik and Persian poet A. K. Firdausi (935—1020). Lucian of Samosata (120—about 180) described a storm which carried a ship up to the Moon.

Theological dogmatism in the early Middle Ages banned the "space" theme from literature, and it only reappeared during the Renaissance. J. Kepler in *Mysterium Cosmographicum* (*Cosmographic Visions*, publ. 1634) called upon magic powers to make a visit to the Moon. Somewhat later the British writer F. Godwin in his imaginative story *The Man in the Moone* (publ. 1638) used trained swans to reach the Moon. The German author H. J. Grimmelshausen made use of the same method in his novel *Der abenteuerliche Simplizissimus* (*The Adventurous Simplizissimus*, 1669, 6 vol.). The German naturalist A. Kircher again called upon magic powers for

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a flight in the heavens (*Itinerarium extaticum quo mundi opificium, Ecstatic Voyage to the Skies*, 1656). F. M. Voltaire in *Micromegas* (1752) wrote of the interplanetary wanderings of a Saturnian.

As science and engineering advanced with the years, they began to greatly influence the methods of space travel devised by fiction writers. Among the many fantastic means of flight described by Cyrano de Bergerac in his *L'autre monde ou les états et empires de la Lune* (*The Other World, or the States and Empires of the Moon*) (1657), one was propulsion by successive firing of powder-fuelled rockets. The English poet Byron in *Don Juan* (1819—1823) considered it plausible to reach the Moon with the aid of a steam engine. Edgar Allen Poe wrote a tale in 1835 in which his hero flew to the Moon on a balloon (*The Unparalleled Adventure of One Hans Pfaal*). A rocket-propelled vehicle was used in *A Voyage to Venus* by the French author A. Eyraud. Alexandre Dumas in *Un voyage à la Lune* (*A Voyage to the Moon*) (1857) thought up a substance that was repulsed by the Earth. Jules Verne in his well-known Gun Club series of novels (1865—1870) sent his heroes to the Moon in a cannon shell. Flight from the Moon to Venus and Mercury attempted by the characters of the French novel writers G. Faure and H. Graffigni (*Les aventures extraordinaires d'un savant russe, The Extraordinary Adventures of a Russian Scientists*, 1889—1896) was provided by the sunlight pressure applied to the vehicle by means of a fixed screen. H. G. Wells in 1901 wrote his romance *First Men in the Moon* in which he brought forward the idea of a gravitational shield. The German writer Kurt Lasswitz in *An zwei Planeten* (*On Two Planets*, 1897) wrote of a substance which made his spacecraft weightless. A. A. Bogdanov in his story *Krasnaya zvezda* (*The Red Star*, 1908) thought up anti-matter for use in conjunction with a reactive engine for making a flight to Mars. In 1913, B. Krasnogorsky wrote a story *Po volnam efira* (*On the Waves of Ether*) in which a large screen made use of the pressure of sun radiation to propell a spaceship to the Moon and back to Earth.

After the appearance of the works of K. E. Tsiolkovsky, R. Esnault-Pelterie, R. Goddard, and H. Oberth, rocket engines became the main sources of propulsion in science fiction. The use of nuclear energy found its way into fiction as early as 1915 (A. Train and R. Wood, *The Man Who Rocketed the Earth*). Besides this, electrical and, primarily, chemical energy became favoured sources of motive power for space flight in science fiction. From the beginning of the 20th century, stories about space flight increased greatly in number; among these were *Vne zemli* (*Outside the Earth*, 1920) by K. E. Tsiolkovsky, *Aelita* (1923) by A. N. Tolstoi, *Pryzhok v nichto* (*Jump into Nothing*, 1933) and *Zvezda Kets* (*Kets Star*, 1936) by A. R. Belyaev, and many other stories.

Today science fiction, in the main, deals with the problems of space flight, e.g., *Astronauci* (*Astronauts*) written by Stanislaw Lem in 1951, *A Fall of Moondust* written by A. Clarke in 1961. Quite often space serves as a background for speculation on the social relationships that may appear in some future generation, e.g., *Tumannost Andromedy* (*Andromeda*) by I. Efremov (1957), *Oblok Magellana* (*Magellanic Cloud*) by Stanislaw Lem (1956), and many other stories. Space stories also sometimes expose some of the shady sides of modern bourgeois society, as *The Martian Chronicles* (1950) by Ray

Bradbury. Owing to the fact that modern science leaves practically no hope for discovering living beings on other planets of the solar system, the theme of interstellar and intergalactic flights is becoming usual in science fiction.

SPACE LAW. A new branch of international law whose purpose is to govern the relations between different nations, arising during exploration of outer space including the Moon and other celestial bodies.

The beginning of space law dates from the time of the launching of the first Earth satellites and other spacecraft, both manned and unmanned. Since space activities affect the interests of all nations, there arises a necessity for regulation of these activities on an international basis, i.e., the establishment of international rules for the use of outer space and celestial bodies.

Space being radically different from all other environments hitherto used by Man, both in physical properties and in the nature of equipment used to explore and utilize it, the legal norms of such branches of international law as aeronautical or marine law are inapplicable to this new field of human endeavour. On the other hand, since space is the scene of human activities and of interacting interests of many nations, space law cannot be formulated in isolation from the rest of international relations, and space activities must come within the general frame of recognized norms and principles of contemporary international law.

Formulation of the norms and principles of space law began in the 1960s, immediately following the commencement of exploration and utilization of space, signalled by the launching of the world's first man-made Earth satellite in the USSR on October 4, 1957.

Like any other branch of international law, space law is based primarily on international agreements. An essential part in the formulation of the main principles of space law is played by the UNO within whose general framework a series of resolutions and drafts for international agreements related to space law were formulated and adopted. At present the norms and principles of space law are found in the following international documents: the 1963 Moscow *Agreement Banning Nuclear Tests in the Air, Outer Space or Under Water*; the 1967 AGREEMENT *on the Fundamentals of National Activities in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies*, as well as a whole list of bi-lateral and regional inter-governmental agreements for co-operation in space exploration and implementation of joint space programmes, e.g., the 1965 Soviet-French agreement.

Any mention of the formulation of the basic principles of space law must include reference to UN General Assembly resolutions 1472 (XIV) of December 12, 1959; 1721 (XVI) of December 20, 1961; 1802 (XVII) of December 14, 1962; 1884 (XVIII) of October 17, 1963; 1962 (XVIII) of December 13, 1963 (containing the *Declaration of the Legal Principles Governing National Activities in the Exploration and Uses of Outer Space*); 2130 (XX) of December 20, 1965, and 2222 (XXI) of December 19, 1966.

The principles of international space law are under study by many international governmental and non-governmental bodies as well as national agencies. One of these is the United Nations Committee on the Peaceful

Use of Outer Space set up in 1959, incorporating Scientific and Technological and Legal Subcommittees.

In the Soviet Union the central space law research and co-ordination agency is the Space Law Commission of the Academy of Sciences of the USSR, formed in 1959.

Soviet diplomacy and science play a leading part in the formulation of progressive norms and principles of space law.

The USSR has advocated formulation of the basic principles of space law since the onset of the space age. As far back as March 1958 the USSR proposed an international agreement for co-operation in the peaceful use of outer space, thus initiating this question at the UNO. The Soviet Union sought and achieved the adoption of a series of major international documents governing national activities in the exploration and use of outer space.

For a number of years the USSR insisted on the conclusion of an international agreement on the basic principles governing the activities of different nations in the exploration and use of outer space. In 1966, at the 21st Session of the General Assembly, the USSR suggested the discussion of the question on conclusion of an international agreement on the principles governing national activities in the exploration and use of outer space, the Moon and other celestial bodies. A relevant draft agreement was submitted by the USSR on June 16, 1966, and, in a revised form, on October 5, 1966. The terms of reference of the Soviet draft covered all outer space, including the Moon and other celestial bodies. The draft embodied and further developed the principles formulated in the UN General Assembly Declaration 1962 (XVIII) of December 13, 1963, and in the UN General Assembly Resolution 1884 (XVIII) of October 17, 1963. The principle of using the Moon and other celestial bodies exclusively for peaceful purposes found due reflection in the draft.

In late 1966, the UN Committee for Peaceful Use of Outer Space worked out and the 21st Session of the General Assembly approved the agreement *On the Fundamentals of National Activities in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies.* This agreement provides that the depositary states will be the USSR, the USA and the UK. Accordingly, the depositary states signed the agreement on January 27, 1967, in Moscow, Washington and London, after which the agreement was accessible for signing by other states. Such an international agreement was signed for the first time in history. Due to the fact that the exploration and use of outer space had greatly increased and rocketry and space technology had made outstanding advances, it became a matter of urgency to work out an international agreement which would set forth the basic legal principles to be observed by the nations carrying out activities in outer space. It is for this reason that the agreement signed has found unanimous approval by the UN General Assembly. International co-operation in outer space based on equality, as provided by the agreement, will enable all countries to take an active part in peaceful space activity to the benefit of all nations. The agreement was a step forward in the development of the co-operation and mutual understanding of states and peoples, and it will facilitate the solution of the most important international problems facing humanity.

Today it is possible to speak of the process of establishment and affirmation of the following basic norms and principles of space law: freedom of exploration and use of outer space and celestial bodies; partial demilitarization of outer space and complete demilitarization of celestial bodies; banning of national usurpation of outer space and celestial bodies; spreading basic principles of international law, in particular the UNO Charter, to include activities in the exploration and use of outer space and celestial bodies; retaining sovereign rights of states to space objects launched by these states and to crews therein; international responsibility of states for national activities in outer space and for damage caused by space objects; prevention of potentially harmful effects of experiments in outer space and on celestial bodies; assistance to the crews of spaceships in the event of an emergency, disaster or forced landing; fostering international co-operation in the peaceful exploration and use of outer space and celestial bodies.

Recognition of the principle of freedom in exploration and use of outer space and celestial bodies does not justify arbitrariness and lawlessness in this new sphere of human activity. The space activities of nations should be carried out for the benefit and in the interests of all humanity, in conformity with international law, in the interests of maintaining peace and security in the whole world, and development of international co-operation and mutual understanding, with due allowance for the interests of other nations. In their activities in the use of outer space, the different nations should be guided primarily by such basic principles of international law as non-aggression (ban on aggression), peaceful solution of disputes, disarmament and banning of war propaganda. Outer space and celestial bodies cannot be subject to national usurpation. The 1963 Declaration further specifies that such usurpation cannot be effected either by the proclamation of sovereignity in outer space and celestial bodies, or by their use or occupation, or by any other means. Each nation which has registered an object launched into outer space retains jurisdiction and control over this object and any crew therein during their flight in outer space. The title to such objects and their constituent parts is retained irrespective of their location. This principle has found its reflection in the 1967 Agreement.

The declaration institutes international responsibility of states for all national activity in outer space and establishes international liability for damage caused by artificial space objects. Therefore, if, in any country, private companies are allowed to take part in activities in outer space (as is done in the USA), the international liability for their activity must be borne by the respective state. In contrast to international aerospace and marine laws, space law does not recognize international liability of the operator. The 1967 Agreement treats this matter in a similar manner.

The principle of freedom of scientific research in outer space does not entitle any state to act to the detriment of others. Therefore, the different nations should abstain from space experiments producing potentially harmful effects, as well as from any activity which would interfere with the peaceful use of outer space by other countries (see Article IX of the 1967 Agreement). The 1967 Agreement also confirms the possibility of conducting international consultations with a view to removing any obstacles in the way

of using outer space which may arise as a result of some experiment or other. The Agreement includes a provision according to which all nations shall regard spacemen as envoys of humanity to outer space and render them every possible aid in case of accident, disaster or forced landing (see Article V of the 1967 Agreement).

The USSR has long advanced the principle of exclusively peaceful use of outer space, affirming that this problem could be solved within the framework of general and complete disarmament. This initiative in favour of peace, however, has met with the resistance of some states. In the opinion of US official circles, it is permissible to allow measures of a military nature, provided they are not acts of direct aggression. From this standpoint, measures of a military nature such as a system of long-distance military communication with the aid of satellites, espionage from outer space, etc., could be realized. It is obvious that the principle of peaceful use of outer space should exclude any measures of a military nature whatsoever.

The recent advances in the use of satellites for long-distance radio and TV communication make the development of legal principles in this sphere particularly important. The organization of control of the international system of long-distance radio communication via satellites and its operation should embody the principle of equal co-operation of all nations without discrimination. The commercial system of long-distance radio communication via satellites established in 1964 on the initiative of the US is incompatible with this principle. This "international" system is actually an American joint-stock company with foreign participation under complete US control. The virtual owner of the space segment of the system is the American private company ComSat Corp. which holds 61% of the total capital of the international consortium comprising $ 200,000,000. Accordingly, the US controls 61 out of the 100 votes in the International Committee, the highest authority of this consortium. At the same time, such countries as Austria, Belgium, Denmark, Ireland, Holland, Portugal, and Sweden have to join forces to obtain one vote in this body. The 1964 Agreement was a serious obstacle in the way to setting up an international system of long-distance radio communication via satellites.

The results of space exploration are not of a national, but of an international character. In the process of assimilation of space by different nations there arise and will arise many new legal problems. Space law is in the stage of formation. Under discussion at present is the question of concluding agreements on the rescue and rendering of aid to spaceship crews in case of disaster, and on compensation of damages caused by launching of space objects. The regulation of launchings and use of meteorological and communications satellites has become a rather actual problem. As cosmic activity extends, of great importance in the demilitarization and neutralization of outer space.

The principal Soviet proposals of 1958 for banning the military use of outer space have become part of the Soviet programme of general and complete disarmament. By agreeing to destroy combat rockets and establish international control to see that rockets and space vehicles are launched exclusively for peaceful scientific purposes, the states would ensure demili-

tarization and neutralization of outer space. From the point of view of international law, demilitarization of outer space means the ban, within this space, on any activity pursuing military ends in peacetime, and neutralization is the elimination of this space from the sphere of military operations in the event of an armed conflict. The demilitarization and neutralization of outer space may be either complete or partial. Complete demilitarization would mean a ban on placing within this space any military objects as well as on flight of such objects through outer space. Thus, the complete demilitarization of outer space would imply a ban on: launching of any military objects into a circumterrestrial orbit; erection of any military objects on celestial bodies or launching such objects into orbit around them; use of outer space for (or during) military manoeuvres or for the purpose of testing any weapons (e.g., nuclear bombs or other means of mass annihilation, combat missiles, combat aerospace devices, etc.). Accordingly, complete neutralization of outer space would mean a ban on the use of this space in war time for: launching military space objects with the purpose of inflicting damage on the enemy; direct combat operations; flight of combat rockets of one nation to targets in the territory of another. In the event of partial demilitarization and neutralization a ban is imposed on certain kinds of activity of states in outer space, which are strictly defined in an international agreement.

It is also necessary to solve such an intricate problem as the demarcation of air space and outer space, since the air space is under the full and absolute sovereignty of the respective nation, while outer space, as far as it extends, is free for use by all nations.

The youngest branch of international law, space law is called upon to ensure conditions enabling outer space to become a zone of lasting peace, an arena of fruitful co-operation for the good of mankind.

SPACEMAN. See COSMONAUT.

SPACEMAN'S COCKPIT. The control board provided in the spaceman's cabin and usually consisting of one or several panels that carry control devices (handles, push-buttons, switches) and indicating instruments and gauges for monitoring and control of the spaceship systems. The indicating instruments are sometimes arranged on a separate panel called the COCKPIT INSTRUMENT PANEL.

SPACEMAN'S HYGIENE. The spaceman's daily personal care routine, such as care of skin of the face and body, the mouth, prevention of perspiration, physical exercises in weightless condition, maintenance of hygienic conditions necessary for sleep, use of hygienic clothing and footwear, selection of types and forms of active rest, etc. The longer the space flight, the greater the importance of the spaceman's hygiene. In the first space flights, the spacemen used only face and hand wash packets. In long-term flights the wherewithal for washing (space shower or bath) must be provided consuming a minimum amount of water. Special eatable pastes that simultaneously serve as prophylactic remedies have been developed for care of the mouth and teeth.

SPACEMAN'S RATION. A scientifically grounded ration for in-flight provisions of a spaceman; it meets all his physiological needs and is determined

experimentally in laboratory conditions and in flight proper. The spaceman's ration is established by studying the peculiarities of metabolism and food requirements due to individual factors of space flight (acceleration, hypodynamia, isolation, etc.) or their combination. As a result, the calorific value of the ration, its chemical composition and the optimal proportioning of various constituents (proteins, carbohydrates, fats, minerals and vitamins) are determined.

The spaceman's ration may consist either of products stored on board the spaceship, or products obtained directly on board in the LSS (see FOOD RECYCLING). Even the first space flights showed that in a state of weightlessness man is able to take food and drink water. This made it possible to develop the principles of the spaceman's nourishment in space flights lasting many days. The calorific value of the spaceman's daily ration was 2500—2700 kcal. In the *Vostok* and *Voskhod-2* spaceships the spaceman's ration consisted of pureed foods in tubes from which the spaceman squeezed the food directly into his mouth. In subsequent flights the spacemen's rations were considerably diversified. They included natural food products, such as beef croquettes, fried beef, veal, chicken fillet, beef tongues, meat puree, sprat patties, caviar sandwiches, fresh fruit, juices, confectionary. To facilitate the taking of food and to avoid its crumbling in conditions of weightlessness, the products were prepared in the form of small pieces and slices. To prolong storage life the rations were prepared and packed according to a special manufacturing plan and under strictly aseptic conditions. The products were packed in double-layer cellophane-polyethylene bags sealed under vacuum. Such rations may be used only in flights of 7—10-day duration; for more extended flights, the rations must be composed only of preserved food. On flights lasting over a month, it is expedient to regenerate water on board the spaceship and to have food stocks consisting of dehydrated products. Such products may be obtained by means of thermal or freeze drying: in these cases they retain their initial volume, colour, taste, odour and biological properties, while their weight is diminished 3—5 times. At the same time, dehydration preserves food products. Most products processed in this way can be stored in ordinary conditions for a year. At lower temperatures the storage period is longer. Dried products can be briquetted. On addition of water, they quickly regain their original properties.

SPACE MEDICINE. The branch of medicine concerned principally with development of methods for selection and training of spacemen, their medical protection in flight, assurance of normal vital activity, health and high working capacity of man in the complicated conditions and specific environment of prolonged habitation in spaceships and on other planets. Space medicine branched out from aviation medicine into an independent field. However, the advancement of aviation has so broadened the scope of aviation medicine that it is now best termed aerospace medicine. The aim of space medicine is to provide the best conditions possible for the spaceman on missions, and to do this it embraces the entire complex of inter-related experiments and measures undertaken in biomedicine, biophysics (see SPACE RADIOBIOLOGY), physical chemistry, mathematics, bio-engineering, telemetry, design and engineering, and a multitude of other spheres.

The factors that may have an effect on the human or animal organism in space flight are generally classified in three groups, *viz.*, (1) factors of space environment (ionizing radiation, meteors, vacuum, etc.); (2) factors of flight dynamics (weightlessness, accelerations, vibrations); and (3) factors determined by long-period stay in an artificial environment of small sealed cabins (isolation, hypodynamia, emotional stress, peculiarities of microclimate). The principal subdivisions of space medicine are: medical service, space physiology, space hygiene, SPACE PSYCHOLOGY, clinical and medical examination of spacemen for fitness. *Medical service* provides for the safety of space flight and comprises MEDICAL MONITORING including warnings of danger to the life or health of spacemen and rendering the necessary aid to spacemen on board spaceships or after landing. Other functions of the medical service are: training of medical personnel; biomedical and physiological studies of the environments of space flight and of other planets; and development of pertinent methods and procedures. *Space physiology* is the field of space medicine that studies the mechanisms of regulation and compensation of physiological functions when the organism is affected by a combination of factors. Special attention is paid to conditions difficult or impossible to simulate on Earth. These are: factors associated with the launching and the powered-flight phase of a spaceship (acceleration followed by prolonged weightlessness, subsequent deceleration during re-entry, and return to normal terrestrial gravitation); cosmic radiation; change of biological rhythms, etc. The laws established by space physiology are the basis for medical prognostication; they facilitate elaboration of optimum schedules for work, rest, sleep, meals and behaviour of spacemen. Space physiology also seeks ways and means of increasing and maintaining the organism's stability in space flight. *Space hygiene* develops hygienic requirements and prophylactic means to keep the crew members healthy and fit to carry on their work (see SEALED CABIN, CABIN HABITABILITY, LIFE SUPPORT SYSTEM.). *Clinical and medical examination* embraces development of clinical and psychophysiological methods for selection and training of spacemen; prevention and treatment of diseases in complicated and specific conditions of habitation; and criteria for precise scientific prognostication of health.

Medical service for non-stop intercontinental flights and the physiological and hygienic studies made in preparation for and during the flights of Soviet fliers in sealed capsules of the stratosphere balloons *CCCP-1* and *Osoaviakhim* (September 30, 1933, altitude 19 km, and January 30, 1934, altitude 22 km, respectively) can be considered the first experiments in a field bordering on space medicine. The LSS used in these flights was designed on the basis of physiological and hygienic principles evolved by Soviet scientists. They discovered and studied the regulating mechanisms of physiological functions of the human organism when effected by such extremely powerful flight factors as HYPOXIA, acceleration, high and low ambient pressure, EXPLOSIVE DECOMPRESSION, etc. These studies advanced the development of flight support medical equipment, such as sealed cabins, oxygen-breathing apparatus, altitude suits, etc. Complex alpine expeditions carried out since 1926 yielded data on the effects of high altitude on the organism (see ALTITUDE SICKNESS), physiological and biochemical mechanisms of adaptation

to it, the effectiveness and duration of acquired adaptation to high altitudes as applied to high-altitude flight in aircraft. For the first time, the conception of limit and failure of adaptability to hypoxia was introduced into aviation medicine, and fundamentals of alpine training to increase the resistance of the organism to the effects of flight factors were formulated. These data have acquired great theoretical and practical significance at the present stage in the development of space medicine. Formation of the basic principles of space medicine was boosted by theoretical and practical principles of medical examination of flight personnel developed between the '20s and '40s. The development of rocket engineering confronted space medicine with new problems that required prompt solution. Of great importance was the successful accomplishment of the programme of biological studies carried out in the USSR with high-altitude geophysical rockets, as well as with *Sputnik II* and other orbital vehicles. These studies facilitated the solution of a number of biomedical problems directly connected with the next stage in the conquest of space by man. Between April 12, 1961, when the first space flight was made by the Cosmonaut Yu. A. Gagarin, and November 1, 1969, 45 Soviet and American spacemen have been out in space. The *Voskhod* spaceships carried space research laboratories. During the flight of a *Voskhod*, the presence of the physician B. B. Yegorov on board made it possible to include in the mission the testing of a number of new apparatuses and methods of rendering medical service in prolonged space flights.

Theoretically and practically, modern space medicine is based on the following classical principles of the natural sciences:

1. *Maintenance of relative stability of the inner medium of the organism* in various conditions of existence: adaptation of physiological processes to the requirements of the organism as a whole. An example of this adaptation, which ensures coordination of the organism's vital functions in changed environmental conditions, is the stability of the inner medium characterized by the stability of the organism's physiological, biochemical and other "constants", such as body temperature, osmotic pressure, active blood reaction, metabolic processes, blood sugar level, ionic composition, arterial pressure, etc. The relative stability of the inner medium enables the organism to resist major environmental changes and thereby maintains equilibrium between them. The equilibration of the organism with the environment proceeds dynamically at the expense of the energy of metabolism. A disturbance in the organism's functions, e.g., that caused by extreme effects, may lead to disturbances in metabolism, in energy exchange and in evacuation of toxic metabolites from the organism. All this affects the optimal conditions for vital activity of cells and tissues. As a result, the tissue and cellular elements become vulnerable, and the progressing functional shifts may cause a pathological state of the whole organism. Hence, in conditions of extreme effects it is especially important to prevent disturbances and exhaustion of the nervous and humoral regulation systems and, in the first place, the mechanisms of the highest divisions of the central nervous system which adjusts the organism's vital activity to the environment. The principle of relative stability of the organism's inner medium is one of the main areas of search for ways and means for developing adequate artificial environment

and normal activity in extended space flights and for organization of orbital and interplanetary stations.

2. *Equilibration of the organism and environment by corticalization of functions*, that is, by direct action of the cerebral cortex upon all physiological systems without exception. Under the action of extreme factors compatible with normal vital activity of the organism, an adaptive reconstruction of functions takes place which is regulated by complicated interaction of the cerebral cortex, subcortex and neuroendocrinic system. The adaptation expands the organism's existence limits to a certain extent by shifting the optimum zone and reducing the organism's dependence on the environment. As a result, the vital activity of the organism attains a new functional level, which gives rise to new peculiarities in the organism's reaction to both direct action of extreme factors (depending on their force, frequency, duration, intervals between them, etc.) and effects occurring during restoration of functions to their initial level (after-effects). The latter involve a complex of metabolic and structural changes and constitute an important integral index, enabling one to judge the functional state of regulation systems, the reactive capacity of the organism and its potential powers of compensation. The more intimately the highest divisions of the central nervous system control the organ's functions, the more rapidly and pronouncedly they change and the shorter the time required for restoration to the initial level. However, functions controlled substantially by humoral mechanisms of regulation, especially those regulated by highly autonomous intramural structures of the nervous system, show a comparatively high stability in similar conditions. But, if these functions undergo changes, the latter are rather stable and are characterized by persistent after-effects manifested in the development of vegetative disturbances in individual organs even within a united functional system. For example, under certain conditions of hypoxia or transversely-directed acceleration (8 g, lasting 3 min) the bio-electrical activity of the brain and heart were restored in a few min, the activity of gastric glands, in several h, and the activity of intestinal glands (according to the activity of enzymes), in several weeks. The after-effects, which are of different duration for different organs, offer an idea of the correlation of the organism's functions and help to reveal the hidden effects of strain when there are no acute reactions and the beginning of the "disintegration" of the organism as an integrated system is established. The relative stability of the dynamics of cortical processes in the conditions described is, probably, due to both protective mechanisms of the cortex proper (protective inhibition) and the subcortical centres of vegetative and neuroendocrinic regulation, which undergo a maximum strain that often exceeds the normal limits.

3. *Integrity of the structure and functions of the organism as a whole under the action of extreme factors.* All the systems of the organism are closely interconnected, and this ensures a general response to various effects, with differentiation of the changes occurring in individual systems and organs; also, the presence of a united system of control and communication in the living organism ensures general adaptation of the whole organism to each particular effect. Space flight involves a number of transitional states; there may be periods of pronounced functional discorrelation when the autonomy

of some systems increases sharply, and they become less dependent on the cerebral cortex. However, the aim of the adaptation process as a whole is to subordinate the specific to the general. The highest control spheres may retain their normal functional abilities at the expense of over-straining the lower (functional and structural) spheres, while the general condition of the organism is quite satisfactory.

During the flight of the *Voskhod-2* spaceship piloted by the cosmonauts P. I. Belayev and A. A. Leonov for the first time in history a man left the cabin of a spaceship to walk in open space. The fact that the cosmonaut Leonov felt good while out in open space is proof of the high quality of Soviet space suits and their autonomous LSS. Equally successful were the extra-vehicular excursions of E. White, E. Cernan, and M. Collins during the flights of the *Gemini* spaceships and, later on, those of Ye. V. Khrunov and A. S. Yeleseyev during their passage from the *Soyuz-5* spaceship into *Soyuz-4*, and that of R. Schweickart out of *Apollo-9*. The veracity of the above theoretical principles has been fully borne out by the orbital flights made by man. All this has enriched space medicine with new, unique data and, consequently, theoretical problems have been raised to a higher level.

SPACE METEOROLOGICAL SYSTEM. A system including spaceborne stations (satellites) which obtain and transmit meteorological data and ground stations which receive and process the information and supply it to world meteorological centres for formulating weather forecasts.

SPACE NAVIGATION. Broadly, the control of spacecraft motion; in a more narrow sense, establishment of the location of the spacecraft regarded as a material particle, forecasting its motion and evaluation of the forecasts from the point of view of achievement of the mission task. Usually, the system of navigation which performs these functions includes both spaceborne and ground measuring and computing facilities. The spaceman may contribute to the solution of navigational problems (see FLIGHT CONTROL).

SPACE PHILATELY. The collection and study of postage stamps and postal stationery of the space series. It includes stamps and blocks, stamped envelopes and postcards and special cancellation commemorating events in space research. The drawings and inscriptions on this postal stationery reflect the history of the space age. Space philately began after the launching of *Sputnik I*, the first Soviet artificial Earth satellite. The first space series stamp was issued in the Soviet Union on November 5, 1957. This stamp depicts *Sputnik I* orbiting the Earth and bears the following inscription: "October 4, 1957. World's first Soviet artificial Earth satellite". In all, 15 space series stamps were issued in 4 countries (USSR, Rumania, GDR, CSSR) in 1957. By 1969, 88 countries of the world had released space series stamps. On this subject some 200 stamps have been issued, half of which commemorate space effort of the Soviet Union. Nearly 200 space series stamps and 100 artistic stamped envelopes have been issued in the USSR. Unique features of Earth satellites, automatic interplanetary stations and other spacecraft are shown on Soviet stamps. Many stamps bear scientific information about space flights that have become history. Of interest is the stamp that gives an account of the flight of *Luna-3*. In an area of about 10 cm^2 it shows the flight path of this automatic station and

different relative positions of the Moon and the rocket at various moments of time, as well as a 48-word explanatory text and the values of 5 measurements. Another stamp commemorating the same flight shows the lunar globe bearing the names of surface features on the far side of the Moon photographed by *Luna-3*. A special section covers pioneering space research. It includes stamps and postal stationery dedicated to researchers in the theory of space flight and rocketry, K. E. Tsiolkovsky, N. I. Kibalchich, N. E. Zhukovsky, Y. V. Kondratyuk and F. A. Tsander, and stamps telling of the flights of the *CCCP-1* and *Osoaviakhim* balloons. The space collection gives an account of prominent events in international collaboration in peaceful use of outer space and commemorates space-philately exhibitions. Space philately also includes symbolic stamps that do not commemorate a particular event in the exploration of outer space, but have satellites and rockets in their general composition, that do not represent any specific type of spacecraft.

SPACE PROBE. A vehicle for space flight or operation on other celestial bodies (e.g., a spacecraft, an automatic lunar station, etc.).

SPACE PROGRAMME OF FRANCE. France's space programme is implemented by the Centre Nationale d'Etudes Spatiales (CNES) established in 1961. It was inaugurated by a comprehensive programme of geophysical research with space probes (*Véronique*, *Vesta*, *Dragon*, *Bélier*, *Centaure*, and *Eridan*) and high-altitude balloons. On November 26, 1965, France became the third power to independently launch space vehicles. The first French Earth satellites (*Diapason*, *Astérisque*, *Diadème*, and *FR-1*) were designed for geophysical exploration. They were injected into orbit by the French *Diamant* and the American *Scout* launch vehicles. The basis of the French national space programme is development of various types of Earth satellites such as the *Dioscures* to aid air navigation, the *Condor* for meteorological service, *Roseau* for radio exploration of the Earth's magnetosphere during the period of greatest solar activity, the *Saros* for communication, and others. They are to be injected by the advanced French launch vehicles *Super Diamant*, *Diogène-II*, *Vulcaine*, and *Régent* from the new space centre in French Guiana.

France's extensive participation in international space programmes includes co-operation with West European countries in the development of the *ESRO* and *HEOS* scientific satellites and the *Europa-1* launch vehicle (2nd stage, the *Coralie*, developed by France); co-operation with the USSR in colour TV communication via the *Molniya-1* satellite, and with the GFR in the development of the *Symphonia* communication satellite; and with the USA in the *Eole* programme that envisages the employment of Earth satellites to collect meteorological data from balloons sent to a definite height.

SPACE PROGRAMME OF GERMAN FEDERAL REPUBLIC. Includes studies of the upper layers of the atmosphere and ionosphere, the geomagnetic field and cosmic radiation. The launching of the *605 A-1* Earth satellite is planned, which should study the Earth's radiation belts and the radiation of solar flares. The satellite will be put in orbit by a US launch vehicle *Scout*. The GFR is preparing in collaboration with the USA to send a space

probe to Jupiter. As a member of ESRO, the GFR is participating in the development of the *HEOS-A* satellite. In the ELDO programme it is responsible for the 3rd stage of the *Europa-1* launch vehicle.

SPACE PROGRAMME OF GREAT BRITAIN. Includes geophysical experiments using British sounding rockets *Skylark*, *Black Knight*, *Blue Streak*, *Jaguar*, *Skua*. A more powerful rocket (*Petrel*) is under development. In co-operation with the USA, Great Britain has designed and manufactured the scientific equipment for the *Ariel* (*UK-1* and *UK-2*) Earth satellites intended for investigation of the ionosphere. These vehicles were orbited in April, 1962, and on March 27, 1964. The next satellite of this series (*UK-3*) was entirely British. Under development at present is a three-stage launch vehicle *Black Arrow*. There is also a project for a three-stage rocket glider *Mustard*. Great Britain is participating in the designing of the *ESRO-1* and *ESRO-2*, *HEOS-A*, *LAS* Large Astronomical Satellite, and communications satellites. Great Britain's participation in the ELDO programme consists in manufacturing the 1st stage of the *Europa-1* launch vehicle, for which purpose the *Blue Streak* rocket is used.

SPACE PROGRAMME OF ITALY. Provides for the development, jointly with the USA, of the *San Marco* Earth satellite for studying characteristics of the ionosphere and atmosphere in the equatorial region. The first satellite of this series was launched in 1964 by the US *Scout* rocket; subsequent satellites of this series (of which 12 are planned for construction), are to be launched from a sea platform established in the equatorial part of the Indian Ocean. Space research groups set up in Italian universities are carrying out an extensive programme of studies of the Earth's atmosphere and ionosphere, cosmic rays, and solar X-radiation. Italy is a member of ESRO and ELDO; university space-research groups are participating in preparations for experiments to be carried out by space probes and the *ESRO* satellites. Italy is taking part in the development of the first *ELDO* experimental Earth satellite, which will be launched by the *Europa-1* rocket.

SPACE PROGRAMME OF JAPAN. Envisages study of the upper layers of the Earth's atmosphere and of outer space with the Japanese sounding rockets of the *Kappa* and *Lambda* series. A more powerful sounding rocket, the *Mu*, is now under development. A modification of this rocket will eventually be used to launch the first Japanese Earth satellite to study the ionosphere, cosmic and solar radiation. Its launching into orbit is planned for 1969. The plan also includes development of meteorological, navigation and communications satellites. The plan for USA-Japan joint space work provides for Japanese-manufactured equipment to be installed on several US sounding rockets.

SPACE PROGRAMME OF USA. Carried out by the NASA, the Department of Defence, and the Department of Commerce of the USA. Principal fields of interest: manned space flight, development of utility satellites, space research of circumterrestrial and interplanetary space, exploration of the Moon and planets. The programme of manned space flights includes: the *Apollo* project, the flight of a three-man spaceship to the Moon with a landing mission on the lunar surface (since 1969); *Gemini* project, which has been fulfilled (following completion of the *Mercury* programme) as a preparatory step

to the *Apollo* project, and which provided for orbital flights of a two-man spaceship to study orbital docking techniques, extravehicular activities of astronauts, and problems of spaceman response to extended spaceflight; projects of manned orbital laboratories. The utility satellite programme involves: communications satellites, including the *Early Bird* and *Syncom* synchronous satellites and satellite systems for global radio communications; meteorological satellites of the *Tiros*, *Nimbus*, and *ESSA* series; systems of navigation satellites for air and sea navigation; satellites for biological experiments in space; geodetic satellites of the *SECOR* series; technological satellites for the development and testing of systems and equipment (*Satar*, *Start*; *ATS*). The programme of scientific research of terrestrial and interplanetary space includes: *Explorer* satellites for studies of the atmosphere, cosmic radiation and micrometeoric particles; *RAE* (*Radio Astronomy Explorer*) satellite for studying the radio emission of celestial objects; *OAO* (*Orbiting Astronomical Observatory*), *OGO* (*Orbiting Geophysical Observatory*), *OSO* (*Orbiting Solar Observatory*), *IMP* (*Interplanetary Monitoring Platform*) satellites for studying interplanetary radiation and magnetic fields in the vicinity of the Moon and the Earth; *Pioneer* space probes (satellites of the Sun) for obtaining information about solar wind. The programme of lunar and planetary exploration includes: *Surveyor* spacecraft for soft-landing on the Moon to explore the lunar surface and transmit telemetry data and photography to the Earth (for the purpose of choosing a landing site for the *Apollo* spaceship); *Lunar Orbiter* spacecraft for photographing the lunar surface and studying conditions in the vicinity of the Moon (preparatory to executing the *Apollo* project); the *Mariner* automatic interplanetary station for fly-by mission to Mars and Venus to obtain scientific data about the planets; the *Voyager* automatic interplanetary station for landing on Mars and carrying out exobiological and atmospheric studies there.

SPACE PSYCHOLOGY. A branch of psychology, that originated in the period of preparation for the first space flights. It is based on the achievements of general psychology and physiology. Space psychology is closely linked with HUMAN ENGINEERING and aviation psychophysiology. Space psychology reveals individual peculiarities unfavourable for spaceman's activity, or effaced psychopathological features (e.g., sequelae of craniocerebral injuries), advances new problems pertaining to the selection of the best and most reliable candidates. The data obtained from experimental psychological studies are considered in the general system for evaluation of the spaceman's neuropsychic and somatic state, and his general physical and special fitness. The progress in experimental psychological studies is characterized by wide use of modern methods. In-flight studies make it possible to evaluate the spaceman's activity. The use of purely psychological tests (such as handwriting, space and time perception test, etc.) is of secondary significance. The principal problems of space physiology are the evaluation of the effects produced by so-called "situational factors" (isolation, monotony, restriction of stimuli, spatial tension) upon the spaceman's activity (ecological psychophysiology), and determination of psychological compatibility of spaceship crew members (group psychology).

SPACE RADIOBIOLOGY. A branch of biology concerned with immediate and remote responses of man and other organisms of the biological LSS (BIOCOMPLEX) to the effects of cosmic radiation. Space radiobiology also studies the combined effects of cosmic radiation and other extremum factors of space flight on the spaceman and biocomplex; it determines the biological effects produced by various components of cosmic radiation; establishes dose levels of cosmic radiation safe for the spaceman and biocomplex; and develops ways and means of protecting the crew and biocomplex against cosmic radiation hazards.

SPACE RADIO COMMUNICATIONS SYSTEM. According to the terminology adopted by the Extraordinary Administrative Conference on Radio Communication (Geneva, 1963), such a system is defined as a system of radio communication between Earth and space stations; between space stations; between Earth stations when the signals are relayed by outer space stations or reflected from bodies in outer space, excluding the reflection or dissipation of the signals by the ionosphere or within the atmosphere.

SPACE ROCKET. The rocket designed to launch unmanned or manned spacecraft into outer space, or to other celestial bodies and to place artificial satellites in orbit round the Earth. Space rockets today are multistage launch vehicles with payloads; in the event of a deep-space flight they are usually launched into a circumterrestrial parking orbit from which they are started off on their deep-space mission (see SPACECRAFT).

SPACE ROCKET ENGINE. A rocket engine designed for SPACE ROCKETS. The liquid-propellant engine, mounted on all LAUNCH VEHICLE stages, as well as stages started from a near-Earth parking orbit or in distant space flights, is the basic type of space rocket engine. Solid-propellant engines are sometimes used, too. Nuclear and electric rocket engines are being developed. Rocket engines usable only in outer space are: electric, solar, radio-isotope, and the hypothetical photon rocket engines, as well as engines using interstellar gaseous hydrogen as the working fluid. Auxiliary space rocket engines used on spacecraft are the vernier, stabilization, attitude control, midcourse correction, retro, and personal engines.

SPACESHIP. A SPACECRAFT intended for manned flight in space. A distinctive feature of spaceships is that they have a sealed cabin with an LSS, a re-entry body, a system of orientation and flight control, and rocket engines to carry out orbital manoeuvres and landing. Spaceships for flight on geocentric orbits are sometimes termed satellite-spaceships. Among the spaceships which have been developed and flown are the Soviet VOSTOK, VOSKHOD and SOYUZ and the American MERCURY, GEMINI and APOLLO.

SPACE STATION. A service station operating in space. According to their purpose (scientific research, communication, navigation, meteorology, etc.), space stations are termed as space scientific stations, space communications stations, etc. If the space station is an Earth satellite, it is usually called a scientific satellite, communications satellite, navigation satellite, etc.

SPACE SYSTEM. A group of ground and space stations acting in co-operation to provide a space service (e.g., meteorological, navigational, radio relaying, or other services). The independent systems are classified as meteorological space system, navigational space system, etc.

SPACE TOXICOLOGY. A branch of toxicology concerned with biological effects of toxic substances which may form in the SEALED CABIN of a spaceship. The sources of such substances may be equipment trouble, lubricants, covering materials, operating electronic equipment, and, primarily, man himself. Several hundred different materials are used for the cabin. In normal conditions, over 20 different chemical contaminants were found in the CABIN ATMOSPHERE. Man produces over 400 compounds belonging to 22 chemical groups. Man's saliva was found to contain ammonia, acetone, methanol and other compounds totalling 149; the total number of substances contained in man's feces is 206, urine, over 150 and skin excretions, over 270. The more perfect the cabin sealing system, the more complicated the purification of its atmosphere from noxious contaminants. LSS provide complete purification of the atmosphere and its conditioning. Studies of space toxicology are of prophylactic importance.

SPACE VACUUM. Vacuum existing in space. It is very high compared with that attained in laboratories. The interplanetary medium at the Earth's distance from the Sun has a mean density close to 10^{-22} g/cm^3.

SPACEVISION. Direct relaying, to TV broadcasting networks, of images received from spaceships, automatic interplanetary stations or satellites in orbit or on the surface of other planets. The TV signals sent by the spacecraft radio equipment, are received by a ground radio communication station and passed on to a TV centre from where they are relayed to the USSR, Intervision and Eurovision broadcasting networks. Spacevision was initiated when Pilots-Cosmonauts A. G. Nikolayev and P. R. Popovich were shown on board the orbiting *Vostok-3* and *Vostok-4* spaceships in August, 1962.

SPECIFIC HEAT RATIO. For the expansion of gases in the rocket nozzle, this is a value determined from the adiabatic flow equation linking pressure and density of gas in the combustion chamber and in the nozzle exit section. When determining the gas density (or, correspondingly, pressure), the processes of DISSOCIATION and RECOMBINATION are taken into account. The adiabatic flow equation applies to gas with a constant chemical composition and in this case is assumed to include the expansion of gas with a variable chemical composition. That is why only rough estimation of parameters is possible when calculations are made using equations of gas dynamics based on the adiabatic flow equation. The thus established specific heat ratio is used for profiling of rocket nozzles because in that case the error is negligible.

SPECIFIC IMPULSE. The impulse developed by a rocket engine per 1 kg of earth weight (at sea level) of consumable propellant (working fluid). Specific impulse is the most important characteristic of a rocket engine. There is a difference between specific impulse in vacuum and specific impulse in atmosphere (e.g., on Earth). The theoretical specific impulse is determined by THERMODYNAMIC ANALYSIS OF ROCKET ENGINE. The specific impulse depends on the type of propellant (working fluid) used and the level of the engine design. For pump-fed liquid-propellant engines without afterburning of gas generator products, the specific impulse is equal to the total thrust of the nozzles of the thrust chamber and gas generator related to the propellant flow rate through the thrust chamber and gas generator. In this case the

Specific impulse efficiency

engine's specific impulse is equal to the specific impulse of the thrust chamber minus the losses to drive the turbopump unit. These losses amount to 1—2%. They are caused by the fact that the specific impulse of the generator gas exhaust system is lower than that of the thrust chamber. Losses are also due to the vernier nozzles fed by turbine gas. In the best liquid-propellant engines of today, specific impulse in vacuum reaches 350—450 s, and for the best solid-propellant engines, 250—300 s; for nuclear rocket engines it may reach up to 2500 s and for electric rocket engines, about 10,000 s. The greatest possible value of specific impulse ($3 \cdot 10^7$ s) can be attained by the hypothetical photon rocket engine. Specific impulse is identical to SPECIFIC THRUST.

SPECIFIC IMPULSE EFFICIENCY. (specific thrust efficiency) The ratio of the actual SPECIFIC IMPULSE (specific thrust) of a thrust chamber in vacuum to the theoretical one (see THERMODYNAMIC ANALYSIS OF ROCKET ENGINE) calculated for similar values of the EXCESS-OF-OXIDIZING-ELEMENTS COEFFICIENT, the area NOZZLE EXPANSION RATIO and chamber pressure (to be more precise, STAGNATION PRESSURE in the nozzle throat). The specific impulse efficiency is an important criterion of the rocket engine design, it characterizes losses of specific impulse (specific thrust) caused by incomplete combustion, the non-equilibrium process of the working fluid expansion, friction losses in the nozzle due to irregular flow, the multi-phase composition of the stream, etc. Usually, the specific impulse efficiency is equal to 0.90—0.95.

SPECIFIC PROPELLANT CONSUMPTION. The quantity of propellant burnt by a rocket engine in 1 s per 1 kg of thrust developed. It is indicative of the efficiency of the rocket engine. Its value is reciprocal to that of SPECIFIC IMPULSE.

SPECIFIC THRUST. Thrust, in kg, developed by a rocket engine per 1 kg earth weight (at sea level) of the propellant (working fluid) consumed in 1 s; or the operation time, in s, of steady-state operation of the rocket engine with consumption of 1 kg earth weight of propellant per 1 kg of engine thrust, i.e., time (s) of steady-state operation of the engine during which the weight of propellant consumed is numerically equal to the engine thrust. Specific thrust is identical to SPECIFIC IMPULSE.

SPEED INDICATOR. A LINEAR ACCELERATION INTEGRATOR intended for operation within a narrow range of APPARENT VELOCITIES. Speed indicators are used in cases when the apparent velocity of a spacecraft in a certain direction is to be kept close or equal to zero. Thus, in cases when a trajectory correction pulse is imparted to the spacecraft in a given direction, speed indicators provided in the two directions perpendicular to the latter serve for controlling the operation of the rocket engines and preventing, through the control system, the appearance of velocities in these directions.

SPHERICAL ASTRONOMY. The branch of astronomy that deals with mathematical determination of the apparent position of luminaries in the CELESTIAL SPHERE; it is the theoretical basis for determining the exact time and methods of eliminating from observation various forms of influence (refraction, daily and annual aberrations and parallaxes that change the position of the luminary in the sphere, precession and nutation that displace the system of co-ordinates relative to the stars, etc.).

Plate IV

Space philately

SPIN STABILIZATION. A method of stabilizing the angular attitude of one of the axes of a spacecraft by rotating the latter about this axis. Sometimes, spin stabilization is practised during operation of spacecraft rocket engines; in such cases the employment of a system of angular stabilization becomes unnecessary. Spin stabilization is also one of the most simple methods of SINGLE-AXIS ORIENTATION employed, for example, for the ORIENTATION OF SOLAR BATTERIES in long-distance flights.

SPLIT INJECTOR HEAD. The type of MIXING SYSTEM of a liquid-propellant engine, in which the injection of propellant components into the combustion chamber or gas generator is accomplished through slots usually situated concentrically.

SPRAY INJECTOR HEAD. The type of MIXING SYSTEM of a liquid-propellant engine, in which the injection of propellant components into the combustion chamber or gas generator is accomplished through orifices in the injector body, that are usually situated along concentric circles. To ensure better atomization and mixing, all or some of the sprays of fuel and oxidizer intersect.

SPUTNIK. The Russian word for satellite, now generally accepted to denote artificial Earth satellites. It came into universal use in 1957 when the Soviet Union launched *Sputnik-1*, the world's first man-made satellite.

STABILITY of rocket propellant. The ability to retain invariable physical and chemical properties in long-term (several years) storage under various climatic conditions and in space flight. Stable propellants make it possible to store charged rockets for long periods of time. Stability is a very important operating characteristic of a propellant (see PROPELLANT THERMAL STABILITY).

STABILIZATION of spacecraft. See ANGULAR STABILIZATION.

STABILIZED PLATFORM. A platform that does not participate in any angular motion of the spacecraft on which it is installed. The platform is kept precisely in a fixed angular attitude to the pre-set directions. In most cases this is attained by the employment of gyros (see GYROSCOPE-STABILIZED PLATFORM). Stabilized platforms are used for mounting ACCELEROMETERS, STAR SENSORS, high-gain ANTENNAS and other devices that are to maintain a fixed angular attitude. They may also serve as POSITION PICK-OFFS of systems of orientation and angular stabilization.

STABILIZER OF PROPELLANT. An additive introduced into rocket propellant in order to increase its STABILITY.

STAFFORD, Thomas P. (born 1930, Weatherford, Okla.). US astronaut, USAF colonel. Upon graduation from US Naval Academy, served with USAF as interceptor pilot. Graduated from the Air Force Test Pilot School. Co-author of *Pilot's Handbook for Performance Flight Testing* and *Aerodynamics Handbook for Performance Flight Testing*. Joined the NASA group of astronauts in 1962. Acting as co-pilot, made an orbital flight in the *Gemini-6* together with W. Schirra on December 15, 1965. Was sent up into space the second time as command pilot of *Gemini-9* (together with E. Cernan) on June 3, 1966, orbiting the Earth 44 times and covering a distance of 1,900,000 km in 75 h. During this flight, the *Gemini-9* approached an *Agena* target rocket. Was command pilot in space flight made with J. Young and E. Cernan in *Apollo-10* on May 18—26, 1969. The ship went into celenocentric orbit on May 21. He and E. Cernan spent 8 h in the *Lunar Excursion*

Module, debugging its manoeuvring system in circumlunar space; they descended to 15 km above lunar surface. After docking with the spaceship they returned to the Earth. Stafford was in orbit round the Moon 61 h 40 min.

STAGE OF ROCKET. See ROCKET STAGE.

STAGE RATIO. The ratio of the take-off weights, of successive stages of a multi-stage rocket; one of the main structural parameters of a multi-stage rocket which has much bearing on the relative weight of the PAYLOAD. In designing rockets, the stage ratio is usually chosen to be close to the optimum value which provides for a maximum relative weight of the payload.

STAGNATION PRESSURE. The pressure of an isentropically stopped gas flow.

STAGNATION TEMPERATURE. The temperature of an isentropically stopped gas flow.

STANDBY PROPELLANT. An additional amount of propellant, over and above the CALIBRATED PROPELLANT LOAD, for extra expenditures during the POWERED FLIGHT PHASE, in conditions of disturbed flight, or in the case of any deviation of rocket's actual parameters (weight, engine thrust, etc.) from nominal values. Usually, the standby propellant amounts to no more than 2—3% of the calibrated propellant load.

STAR CLUSTERS. Globular and open groups of stars. The globular star clusters contain many thousands of stars and surround the nucleus of the GALAXY. The open star clusters are concentrated near the equatorial plane of the Galaxy and consist of hundreds of stars travelling in the same direction (e.g., the Pleiades).

STARS. Self-luminous gaseous celestial bodies. A typical star is the SUN; the rest of the stars are at giant distances from us. Among those nearest to the Sun are the following stars: α Centauri ($\sim$4.3 light years); Barnard's star ($\sim$5.9 light years); Wolf 359 ($\sim$7.5 light years); Sirius ($\sim$8.8 light years). It is suspected that some stars have invisible satellites with the same mass as JUPITER. The existence of Earth-type life is the most probable on the planets near stars like the Sun, e.g., ε Eridani ($\sim$10.8 light years), τ Ceti ($\sim$11.7 light years). Bright stars seen in the night sky serve for orientation of spacecraft; the most important of them, second in brightness, is Canopus (near the South Pole of the ecliptic). There exist stars whose size and luminosity are much greater (giant stars) or smaller (dwarf stars) than those of the Sun. An important characteristic of a star is the STELLAR MAGNITUDE. The basic method used for the study of stars is the investigation of their spectra by means of instruments and devices located on the ground or mounted on spacecraft, enabling the study of star radiation in the regions of the spectra heavily absorbed by the Earth's atmosphere (X-ray, UV, HF and very-low-frequency radiation). The spectral classes of stars differ in the intensity of spectral lines and the distribution of brightness of the continuous spectra, indicating the temperature in the outer layers of stars. Stars within the same spectral class are differentiated by their physical characteristics. The most marked difference is that between the giant and dwarf stars of recent classes. The former have prolate and rarefied shells, while the latter are characterized by thin and dense shells. At one and the same temperature the percentage of ionized atoms of any metal present in a giant star is larger than that in a dwarf star due to the difference in density. Since a given

spectral class is characterized by a certain mean ionization, a dwarf star is always hotter than a giant star of the same spectral class, the higher temperature of the dwarf star compensating, in a sense, for its denser atmosphere.

The spectra of stars of dissimilar luminosity in most cases differ also in that the spectral lines are wide and vague in dwarf stars, but narrow and sharp in giant stars, which results from the physical condition of the stellar atmospheres. Such differences have been found to exist in stars of almost all spectral classes. Thus, the luminosity classification, a second parameter, is possible by applying the spectrum as a means for determining the absolute stellar magnitude.

A detailed investigation into the stellar spectra allows the determination not only of the chemical composition of a star, but also of its temperature (by the distribution of energy in a continuous spectrum, and by the intensity of the spectral lines), density (by the intensity of the spectral lines), presence of electrical and magnetic fields (by the change in lines dependent on the Stark and Seeman effects), axial rotation (by broadening of lines due to Doppler effect which is dependent on the difference in velocity of an "approaching" or "departing" half of the star disk), motion in space (by a shift of lines due to Doppler effect), the emanation of matter from the surface of the star (by appearance of radiation lines), etc. The physical characteristics of typical stars are given in the Table, p. 436.

Stars can form binary, ternary, or multiple systems. The components of such systems orbit around a common centre of mass. Probably, about $^1/_4$ of all the stars are binary and 10% of them are multiple systems. Binary stars are the only source for determining the mass of the stars. By now, the masses of 250 stars have been found. For some types of binary (eclipsing) stars it is also possible to find the dimensions by observing the orbits of their components and analyzing the curves showing the changes in their brightness. For close pairs of stars the density distribution in stellar interiors can be inferred from the mutual tidal action of the two components.

The stars whose brightness changes periodically are known as variable stars. The changes may be due to periodical eclipses of one star by the other (eclipsing variable or eclipsing binary stars), or, which is the more frequent case, to pulsation, i.e., actual change in the dimensions and temperatures of the star (physical variable stars). The period of pulsation for various types of variable stars may be in the range of a few h to several tens of years. The physical mechanism responsible for pulsation is not yet well understood. The period-brightness relation for certain types of variable stars is constant, which makes them indicators for finding the distances to remote star systems where such stars are observed.

There exists also a large class of non-stable stars which are generally characterized by bright lines in the spectrum. The formation of these lines is attributable to powerful ejection of matter from such stars; such ejection takes the form of explosions in novae, supernovae and nova-type stars, or the form of continuous emanation in case of Wolf—Rayet stars, stars of *P* Cygni type, stars of spectral class *Ve*, etc. In the course of emanation a prolated moving shell forms which re-emits the UV radiation resulting in bright lines in the star spectrum. In shells which are at great distances from a star

PHYSICAL CHARACTERISTICS OF TYPICAL STARS

Stars	Spectral class	Mean density, g/cm³	Luminosity	Mass	Diameter
			fractions of Sun's luminosity, mass and diameter		
I. Super-giant stars					
VV Cassiopeiae *A*	B1	0.001	$2.7 \cdot 10^5$	57	34
ε Aurigae *A*	F2	0.000002	$9.1 \cdot 10^4$	32	251
II. Giant stars					
Aldebaran	K5	0.00002	90	4	60
Arcturas	K0	0.0003	100	8	30
Capella	G0	0.002	150	4.2	12
III. Sub-giant stars					
WW Draconis *A*	G2	0.15	6.3	4.0	2.9
ξ Herculis *A*	G0	0.11	4.8	1.4	2.3
IV. Main sequence stars					
β Centauri	B1	0.02	3100	25	11
Vega	A0	0.1	50	3	2.4
Sirius *A*	A0	0.4	26	24	1.8
Altair	A5	0.6	9.2	2	1.4
Procyon	F5	1.2	5.4	1.1	1.9
α Centuri *A*	G3	1.1	1.12	1.1	1.0
Sun	G3	1.4	1	1	1
70 Ophiuchi *A*	K0	0.9	0.42	0.9	1.0
61 Cygni *A*	K7	1.3	0.21	0.5	0.7
Kruger 60 *A*	M3	9	0.002	0.3	0.3
V. Sub-dwarf stars					
85 Pegasi *A*	G3	3.0	0.41	0.65	0.60
ER Orionis *A*	G1	1.9	0.58	0.49	0.63
VI. White dwarf stars					
Sirius *B*	F	27.000	0.003	0.96	0.0034
O_2 Eridani *B*	A0	64.000	0.003	0.44	0.019

(planetary nebulae, novae stars at later stages) luminosity is due to ionization of atoms from the fundamental state under the HF radiation of stars and subsequent recombinations. Much importance is attached to the light pressure caused by radiation of the nebulae in the spectral line. Of special interest are the phenomena of permanent emission in the spectra of cold dwarf stars with bright lines: a normal spectrum of a star is sometimes superimposed by a radiation in the continuous spectrum and the brightness is

thus greatly increased. Since the flare occurs rapidly, it cannot be accounted for by thermal radiation. There are some grounds for considering such stars to be very young and not stabilized yet.

The main problem in the theory of stellar atmospheres is to find out the mechanism responsible for transfer of radiation. Since in the atmospheres of the majority of ordinary stars the radiation field is stationary, the theory is based on the assumption of the radiative balance (each unit of the volume re-radiates all the energy it absorbs). By studying the transfer of radiation in stellar atmospheres, a theoretical distribution of energy in the continuous spectrum can be obtained. A comparison between the theoretical distribution and the observed one allows the determination of the parameters of the atmosphere (temperature, acceleration of gravity, relative contents of different atoms, etc). These parameters also determine the dependence of the absorption factor on the frequency of the radiation. Qualitative analysis of the chemical composition of the atmospheres of the Sun and stars yielded the knowledge of the abundance of the chemical elements.

The theory of internal structure of stars is based on a conception of a balanced-gas star whose state is governed, on the one hand, by mechanical balance (hydrostatic—between the gravitational force and the force produced by the gas pressure) and, on the other hand, by thermo-dynamic (between the emission and removal of energy).

The main mechanisms responsible for absorbing the radiation in stars are photo-electric absorption and free electron dispersion. The theory of the inner structure of stars is best developed for the stars of the main sequence (see the Table on p. 436) for which the perfect gas equation of state may be employed (due to the fact that the atoms are almost completely ionized in the depth of the star). The population I stars of the main sequence consist of a small convective nucleus ($\sim$0.15 the star's radius) and a radiative shell. The dimensions of a convective nucleus rise with an increase in the mass of the star. Stars of the main sequence, belonging to population II, on the contrary, have a convective outer shell and a nucleus in the state of radiative equilibrium. The smaller the mass of the star, the deeper extends the convective shell. The centre temperatures in stars of equal luminosity vary in the range of 10 to 30 million °K. For some types of stars, the perfect gas equation of state in the central parts is violated and the process of degeneration begins. White dwarfs consist of the degenerated gas practically completely.

The sources of star energy are thermonuclear reactions. For the main sequence stars these are the reactions of hydrogen transfer into helium: the proton reaction and the carbon-nitrogen cyclic reaction. The evolution of stars is mainly dependent on the change in their chemical composition as a result of hydrogen conversion to helium. The evolution may be different depending on whether complete mixing of the star matter takes place (chemical composition changes uniformly throughout the star) or no such mixing takes place (chemical composition changes only in the central part of the star; in this case it is necessary to consider heterogeneous multi-phase models). Another factor of a star evolution is the mass. The stars whose mass remains constant develop differently from those whose mass changes with time (decreases due to corpuscular escape). When hydrogen in a star is exhausted,

reactions are possible in which heavier nuclei are formed from helium if compression of the star leads to an appreciable rise in its temperature and density. The most elaborate theory has been developed for the evolution of stars with constant mass wherein no mixing occurs. Due to such evolution the main sequence stars change gradually into red giants.

STAR SENSOR. A space-borne instrument for directional positioning with reference to a star or a remote planet. Comprises a miniature telescope focused on a sensitive photocell and other auxiliary equipment that permits detection of any deviation of the optical axis of the telescope from the star. Star sensors are used for solution of navigational problems by astronomical methods, for ASTRO-CORRECTION of gyro-stabilized platforms and serve also as POSITION PICK-OFFS in precision systems of orientation.

STARTING OF ROCKET ENGINE. The complex of non-stationary processes taking place in a rocket engine in a preset sequence from the time of the first command to start the rocket engine to the beginning of specified operation. The starting of a liquid-propellant engine is effected by feeding the propellant components into the rocket engine in a pre-set sequence and in the required absolute and relative quantities. Pump-fed engines are started by means of special starting devices (powder, liquid or gas starters) or without them (by pressurization and liquid head in the propellant tanks). Special igniters are used for the starting of engines firing anergolic propellants. High-power liquid-propellant engines are sometimes started in steps, through interim rates of operation.

STARTING PHASE. The phase of flight of a launch vehicle after take-off, during which it retains its initial attitude and moves upwards along a vertical line. The starting phase lasts for a few s. Vertical take-off makes the launching more simple, allows the use of horizontal launching pads and lessens the stresses in the launch vehicle airframe, this being of special importance for large-size space rockets.

STATIONARY EARTH SATELLITE. An Earth satellite that seems to hover above a particular point on the Earth's surface. Stationary satellites are launched eastwards and sent into a circular orbit lying in the equatorial plane at an altitude of about 35,800 km. The Earth is viewed from such a satellite at an angle of 17°, thus making it possible to establish regular radio communication between points on the Earth's surface within a radius of approximately 10,000 km. The stationary Earth satellites that have been put in orbit are *Syncom-3*, *Early Bird* (*Intelsat-1*), *Lany Bird*, *Canary Bird* (*Intelsat-2*), *ATS-1*, *ATS-3*, and *Intelsat-3B*. Nearly stationary are the orbits of the *OV2-5*, *OV5-4* and *LES-6* satellites.

STEADY-STATE ORIENTATION. Maintaining of the pre-set angular attitude of a spacecraft after the latter has been properly oriented. The angular velocity of the spacecraft cannot be fully suppressed due to inevitable operating errors of the sensing elements of the orientation system. As a result, steady-state conditions of orientation are characterized by an angular oscillation of the spacecraft about the required angular position, these oscillations being within the limits of the permissible ERROR OF ORIENTATION. These oscillations are slow and proceed at a rate of a few hundredths of an angular degree per second, i.e., are comparable with the movement of the hour hand

of a clock; spacecraft having a precision system of orientation may oscillate under steady-state conditions at a still slower rate.

STEAM-GAS GENERATOR. The unit of a liquid-propellant engine, that generates steam-gas, i.e., a heated mixture of steam and gas (e.g., the products of decomposition of HYDROGEN PEROXIDE: water vapours and gaseous oxygen at a temperature of 450°—1000°C). Steam-gas generators serve the same purpose as GAS GENERATORS.

STEERING FORCE. The force produced by rocket engine thrust or other means (e.g., a SOLAR SAIL), that drives the spacecraft or RE-ENTRY BODY along the required trajectory. In certain cases no special devices are needed to produce a steering force, e.g., when the LIFT FORCE applied to the re-entry body is used for this purpose.

STELLAR ASTRONOMY. The branch of astronomy dealing with the structure and evolution of stellar systems (such as binary and multiple stars, stellar associations, clusters, clouds and galaxies), interstellar gas and dust. Stellar astronomy solves the problems involved in determination of distances and the study of the laws governing spatial distribution of the above structures, and in their kinematics and dynamics; estimation of the age of stellar systems, etc., by using methods of mathematical statistics and statistical mechanics. The data, theories, methods and conclusions of ASTROPHYSICS and other branches of astronomy are widely used.

At the beginning of the 20th century, on the basis of numerous determinations of stellar distances, the Hertzsprung—Russell diagram was compiled; it shows the connection between stellar luminosities and their temperatures. Integrated studies have made it possible for us to establish the basic laws governing the diverse structural and dynamic features of our GALAXY and a number of other galaxies, e. g., the Magellanic clouds, Great Andromeda Nebula, etc. (see EXTRAGALACTIC ASTRONOMY).

STELLAR CATALOGUES. See ASTROMETRY.

STELLAR MAGNITUDE. The unit of brightness of a luminary. The brightest stars in the sky are of zero of 1st magnitudes; the faintest ones visible by naked eye are of 6th magnitude. Precise magnitudes are established by comparison with reference stars of known luminosity; there are *visual*, *photographic* and *photovisual* (by photographs taken through a yellow filter) stellar magnitudes. Since the colour sensitivities of the eye and photographic materials are not the same, the various scales do not coincide. The difference between the photographic and the visual stellar magnitude indicates the colour of the celestial body and is called the colour index. *Visual* stellar magnitudes correspond to the luminosity of a celestial body as observed from the Earth. *Absolute* stellar magnitude is the brightness a given star would have if it were at a standard distance of 10 parsec.

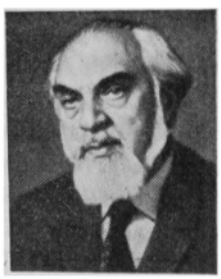
STERILIZATION. Treatment of space objects to destroy bacterial microflora and spores of higher organisms. Sterilization is necessary in order that (a) the biosphere that may exist on another planet be preserved for science in unchanged natural state; terrestrial micro-organisms may irretrievably alter the biosphere or be indistinguishable from local microflora; (b) there is no danger of terrestrial micro-organisms propagating rapidly or acquiring new pathogenic or other harmful properties in new ecological conditions,

since this would greatly impede man's exploration of the planet. In space flights with landings on other planets and subsequent return to the Earth, the problem of sterilization from extraterrestrial microflora will arise.

Absolute sterilization is impossible. With an increase in the duration of any sterilization factor, the number of micro-organisms alive decreases along the exponential curve which approaches zero asymptotically. Therefore, only the probable sterilization of a space object can be considered. Thus, if prior to sterilization a space object has 10^{10} micro-organisms and after sterilization their number decreases 10^{12} times, the probability that the space object is not sterile is 10^{-2}, i.e., a micro-organism remains alive on at least one out of 100 space objects sterilized by that method; this is sufficient to infect a planet.

There are physical and chemical methods of sterilization. Physical methods include heating, hot steam treatment, exposure to UV-radiation, ultrasonic treatment, filtration (for liquids, e.g., fuels). These methods are not equivalent: filtration, and especially ultrasonic treatment are of low efficiency; the best results are achieved by heating and UV-irradiation. Exposure to a temperature of 135°C for 24 h or to a radiation dose of $1.2 \cdot 10^7$ rad reduces the number of micro-organisms 10^{13} times. Most physical methods, however, damage the instruments sterilized (heating, ultrasound) or cause structural changes in materials (radiation); this limits the field and scope of their use. Hence, relatively low temperatures are used for sterilization.

Chemical sterilization can be effected with either a gas (e.g., ethylene oxide), or a liquid (e.g., formaldehyde). As a rule, the effectiveness of chemical sterilization is lower than that of physical one, since the sterilizing agent cannot easily penetrate to all the surfaces treated. In practice, the various parts of a space object and its equipment must be sterilized by different methods with subsequent assembly in a special aseptic chamber. The space object prepared for launching must be sealed in an air-tight shell, to prevent contamination by the atmosphere, as 1 m^3 of the air (at sea level) contains about 10^5 micro-organisms, of which 10^3 are bacteria. The shell is discarded only after the space object has passed through the Earth's atmosphere. Space objects that are to land on planets with atmospheres, are subject to sterilization, as are artificial satellites of such planets, since they may subsequently fall upon the planets. The practical permissible probability of lack of sterility of a space object is 10^{-4}.



STERNFELD, Ari Abramovich (born in 1905). Soviet scientist in the field of cosmonautics. Author of numerous scientific and popular science works, the most important of these being *Vvedeniye v kosmonavtiku*, (*Introduction to Cosmonautics*, 1937) and *Iskusstvennye sputniki Zemli* (*Artificial Earth Satellites*, 1956; 2nd ed., 1958). Awarded the International Prize in Astronautics (1934) and the International Galabert Prize in Astronautics (1963).

STORABLE PROPELLANT. A liquid propellant consisting only of high boiling compo-

nents (oxidizer and fuel), and possessing chemical and physical stability during long periods of time (several years). Storable propellants are extensively used.

STORAGE OF SOLID-PROPELLANT ROCKETS. A structure for long-term storage of loaded solid-propellant rockets and their components. The solid-propellant rockets and their components are placed on store-room dollies, supports or racks. The temperature and humidity of the store-room air is kept at a pre-set level. Hoisting and handling equipment is provided.

STORM ANCHORAGE of a launch vehicle. A set of facilities and devices for keeping launch vehicle in position on the launcher in a storm wind, when firing of the launch vehicle is no longer possible. Storm anchorage includes wind grabs, cable guys, etc. Often storm and WIND ANCHORAGE are combined into a single structure. Storm anchorage is actuated by means of remote-controlled electric, pneumatic or hydraulic devices. Manual installation and dismantling of storm anchorage are used as well.

STRESS-BEARING ELEMENTS. Structural elements designed for reinforcing the rocket shell subject to compressive, tensile or bending forces. The shell of the rocket frame is reinforced by longitudinal (stringers) and transverse (frames) members. The stress-bearing members are made of thin-walled shaped metal.

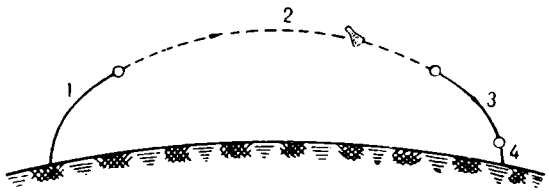
STRINGER. A structural element of the shell, which takes up axial loads; a shaped thin-walled rod.

STRUTCURAL LOADS. Loads acting upon some elements of a space vehicle. Structural loads are computed for all basic phases of flight and ground servicing of the space vehicle and serve as initial data for calculating its structural strength. Structural loads can be static (slowly variable with time) or dynamic including vibrational loads. When in flight, the rocket structure is subject to action of different forces: external (aerodynamic, engine thrust, etc.) and internal (pressure in tanks, etc.). According to their origin, structural loads are classified into aerodynamic, inertial and thrust loads, temperature strains, etc. With respect to the direction they act along, structural loads can be longitudinal (axial), transverse, or torsional.

SUBLIMATION ROCKET ENGINE. A solid-propellant engine in which sublimation of the propellant (e.g., volatile compounds of ammonium) takes place under the influence of heat or an electric discharge. Sublimation micro-rocket engines are used as control and vernier ones.

SUBLIMATION UNIT. A heat exchanger used in the LSS; the heat is abstracted from its source by sublimation of a solid coolant, e.g., ice.

SUB-ORBITAL FLIGHTS. Flights of spacecraft along ballistic trajectories at speeds below the first cosmic velocity, i.e., without entry into an Earth



Suborbital flight trajectory

1—space vehicle powered flight; *2*—ballistic flight; *3*—deceleration by air drag; *4*—parachute descent.

satellite orbit. Sub-orbital flights were performed in 1960—61 by US *Mercury* spaceships. Two of these were manned flights, one being made on May 5, 1961, by A. Shepard and the other, by V. Grissom on July 21, 1961. The maximum duration of sub-orbital flights was about 15 min, the distance, 486—504 km, the altitude, 186—189 km.

SULPHUR BINDING. Conversion of various sulphur-containing compounds into sulphuric acid. During MINERALIZATION of human metabolic by-products and other wastes of the BIOCOMPLEX, various sulphur oxides are formed. This causes sulphur disbalance in LSS based on RECYCLING OF SUBSTANCES. Sulphuric acid may be used for dissolving the solid phase of mineralization in the preparation of nutrient solutions for higher and lower plants.

SUN. The star closest to the Earth, spectral class G2 (yellow dwarf), in motion relative to the nearer stars at a velocity of 19.4 km/s in the direction of the constellation Hercules. The dia of the Sun is 1392 thou. km. The Sun rotates on its axis in the same direction as the Earth (in a plane inclined 7° 15′ to the plane of the Earth's orbit), the rotational speeds differing with the hellographic latitude. The synodic period of rotation of the Sun (relative to the Earth) at latitude $\varphi = 16°$ is 27.25 days. At the equator the circumferential velocity is 2 km/s. The Sun contains 99.866% of the entire mass of the solar system. The mean distance from the Earth is $1.4960 \cdot 10^{13}$ cm. Only the outermost layers of the Sun (its atmosphere, which makes up 10^{-10} of the entire mass) are open to direct observation. Apparently, there is a convective core near the centre of the Sun. The temperature at the centre is $15 \cdot 10^6$ °K, density, ~100 g/cm^3. The mean energy generated inside the Sun in 1 s is equal to 1.88 erg/g and is due to thermonuclear reactions in which hydrogen is converted into helium (proton-proton and carbon cycles; the former is the most probable). Energy is transmitted from interior layers to the outside mainly via absorption of electromagnetic radiation; the energy is re-transmitted from layer to layer with a gradual increase in the wavelength as the temperature diminishes with distance from the centre of the Sun. The effective temperature of the Sun determined by its luminosity is 5785°K. Its mean density is ~1.4 g/cm^3.

The solar atmosphere consists of the photosphere, chromosphere and corona. Nearly all observed radiation of the Sun emanates from the lower part of the atmosphere, or photosphere (100—300 km). The temperature at the boundary of the photosphere is ~4500°K. Directly underneath the photosphere is the convective zone. Evidence of convection is the non-uniform brightness of the photosphere in the form of separate bright grains called granules 100 to 350 km in dia and with lifetimes from 5 to 10 min. Larger clusters of granules (~30,000 km in length) have also been observed. Granules are roughly 300° hotter than the inter-granular space. Features of the photosphere include sunspots (cooler areas with appreciable magnetic fields of ~1000—3000 oe) and faculae (hotter regions in the vicinity of the solar limb). Above the photosphere lies the chromosphere in the form of separate filaments extending to heights of several thou. km. The temperature here increases with altitude and reaches 20,000°K. Observed in the chromosphere are plagues, or flocculi (continuations of faculae), prominences (bright clouds of gas extending out from the solar limb) and filaments (priminences on

the disk that appear as dark formations). The chromosphere is also the seat of extremely powerful explosive processes called solar flares. The so-called corona extends above the chromosphere out to several solar radii. It has a radiant structure and its general shape (like the number of sunspots, faculae, plagues, prominences and other features) varies with the phase of the SOLAR ACTIVITY cycle. The corona has a kinetic temperature of about 10^6 °K; the surface brightness is 10^6 times less than that of the centre of the solar disk. In the absence of special instruments, the corona may be observed only during total eclipses of the Sun.

The Sun's total radiation comes to $3.86 \cdot 10^{33}$ erg/s. The quantity of radiation falling on a plate at right angle to the Sun's rays outside the Earth's atmosphere at the mean Earth—Sun distance is equal to $1.374 \cdot 10^6$ erg/cm^2·s.

Solar radiation consists of electromagnetic and corpuscular emissions. Corpuscular radiation, mainly of protons and alpha-particles with velocities of 500 to 1500 km/s, has a density, at the Earth, of the order of 10 ions/cm^3; densities increase with increasing activity. Solar flares generate particles (principally protons) of high energy (up to $2 \cdot 10^{10}$ eV) that represent a considerable danger to manned space flight. The bulk of the electromagnetic radiation of the Sun lies in the visible part of the spectrum and is emitted mainly by the photosphere. The short-wave and radio emissions emanate from the corona.

SUNSPOTS. See SUN.

SUPERCOOLING OF CRYOGENIC PROPELLANT. Artificial cooling of the cryogenic propellant to several degrees below its boiling point. Loading and metering of the supercooled propellant are facilitated due to the absence of boiling; there are no evaporation losses during the stay of a loaded launch vehicle on the launcher or during flight. Supercooling can be achieved by several methods. The propellant to be filled is passed through a heat exchanger washed by a refrigerant whose temperature is lower than the propellant's boiling point (e.g., oxygen passes through a coil immersed in liquid nitrogen with a boiling point of —196°C or gaseous helium cooled to —200°C). In another method the propellant moves through the following circuit: vehicle tank—centrifugal pump—helium cycle refrigerator—vehicle tank, actual supercooling being effected in the refrigerator by gaseous helium cooled to —200°C. The two above-mentioned methods are termed "direct cooling methods". Supercooling of cryogenic propellant by evacuation consists in the following: by exhaust of propellant vapours from the propellant tank ullage, vacuum is created and the propellant boiling point becomes lower; as a result, the propellant starts evaporating intensively and the energy absorption for evaporation lowers the temperature of the remaining propellant. This method is sometimes resorted to for supercooling of LOX and liquid nitrogen, though it involves high evaporation losses of the propellant.

SUPPLY VEHICLE. A spacecraft designed to ferry loads to a MANNED ORBITAL STATION and to replace the station crew. In some cases this may also be a spacecraft used to deliver a load for accomplishing a lunar or planetary expedition.

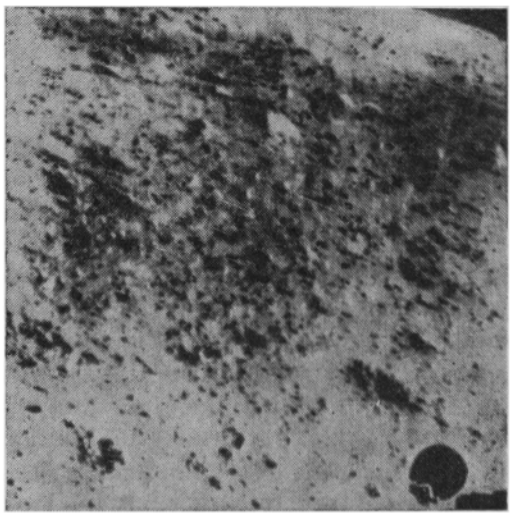
SUPPRESSION OF KINETIC MOMENT of gyrating masses. Duty of the system of orientation which makes joint use of REACTIVE GYRATING MASSES

and ATTITUDE CONTROL MOTORS. As disturbing moments act on the spacecraft, the angular velocity of the reactive gyrating masses increases gradually, which worsenes the spacecraft control efficiency. When the angular velocity attains maximum permissible value, the spacecraft control is transferred temporarily to the attitude control motors while the gyrating masses are decelerated (the kinetic moment of the masses is suppressed); at termination of this process the motors are cut off and the control system of the spacecraft continues to operate as previously. The kinetic moment is also to be suppressed if inertial actuators of any other type are employed instead of the reactive gyrating masses. The kinetic moment can be suppressed gradually (continually) by the combined use of inertial actuators and ELECTROMAGNETIC ACTUATORS.

SUPPRESSION OF SPACECRAFT ANGULAR VELOCITY. Duty of the system of ORIENTATION preceding the establishment of the assigned angular attitude of the spacecraft. During this process, the angular velocity acquired by the spacecraft in the foregoing phases of flight is suppressed, e.g., the angular velocity of a spacecraft that was spin-stabilized in the preceding phase of flight, or the angular velocity acquired by a spacecraft on separation from the launch vehicle.

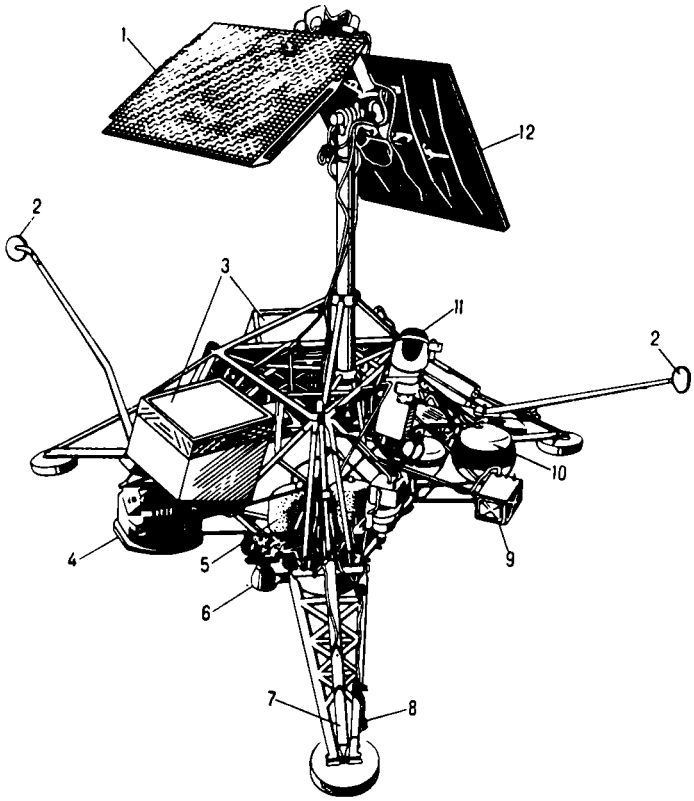
SUPPRESSOR. An additive introduced into a solid propellant in order to reduce its sensitivity to external impulses, or into a liquid propellant in order to increase its stability (propellant suppression).

SURVEYOR. The name of a series of American automatic lunar stations. Their weight on landing is ~280 kg. Each station is provided with a control system and rocket engines for trajectory correction and braked landing. The station's landing gear has three legs with shock-absorbers; it carries a TV camera to take pictures of the lunar landscape and an instrument package. SOLAR BATTERIES supply the electric power required by the equipment. The first *Surveyor* launched on May 30, 1966, landed in the region of Oceanus Procellarum (co-ordinates 43.4° W.L., 2.5° S.L.). The TV images of the lunar landscape transmitted to Earth were similar to those relayed earlier from the Soviet lunar station *Luna-9*. The launching of *Surveyor-2* and *Surveyor-4* miscarried. *Surveyor-3* was launched on April 17, 1967. It landed in the eastern part of Oceanus Procellarum (at 23° 10′ W. Long., 3° 20′ S. Lat.). Besides the TV system, the *Surveyor-3* carried a special mechanical device with a shovel to dig furrows 20 cm deep to study soil of the moon. Launched on September 8, 1967, *Surveyor-5* made a soft landing in the western part of Mare Tranquillitatis (at 23.23° E. Long., 1.48° N. Lat.);



Lunar surface photograph taken by *Surveyor*.

besides relaying TV images, the station made a chemical analysis of the lunar soil with an α-analyzer and magnet and discovered particles of iron; after landing, the vernier engines were run for short periods to test their effect on the upper layer of lunar soil. *Surveyor-6* was launched on November 7, 1967; it landed in Sinus Medium (at 1.48° W. Long., 0.47° N. Lat.); TV images were transmitted and the chemical composition of the ground



American Moon satellite *Surveyor*

1—solar cells; *2*—semidirectional antennas; *3*—packages containing electronic equipment; *4*—landing radar antenna; *5*—propellant tank; *6*—landing retro-rocket; *7*—shock-absorbing landing leg; *8*—attitude control nozzle; *9*—storage battery; *10*—helium bottle; *11*—TV camera; *12*—high-gain antenna (main retro-rocket serving for soft landing is not shown).

analysed; by running the vernier engines for a brief interval (2.5 s) the vehicle was shifted ~4 m from the original landing point, after which TV transmission was resumed. *Surveyor-7*, launched on January 7, 1968, landed in the continental region near Tycho crater (at 11.43° E. Long., 41.01° S. Lat.); it transmitted pictures of the lunar landscape and analysis of chemical composition and mechanical properties of the lunar soil.

SURVIVAL KIT. Kit of supplies and equipment to be used in case of emergency. It includes food and water, hunting and fishing paraphernalia, means of communication and beacons, means of defence, clothes, medicines, bandaging materials, sailing equipment (see RESCUE OF SPACEMEN AND SPACESHIPS).

SUSPENSION. A system in which solid particles are dispersed throughout a liquid. Suspensions of metals and non-metals (e.g., boron, silicon, carbon, aluminium, magnesium, and beryllium) in liquid fuels have been tested in rocket propulsion. In spite of the fact that employment of certain suspensions increases the specific impulse and propellant density, they have not, as yet, found application due to difficulties in gas generation, as well as for the reasons of their instability, high viscosity, and the clogging of the liquid-propellant engine systems. The larger size of the solid particles distinguishes a suspension from a colloidal solution.

SUSPENSION TANKS. Rocket propellant tanks designed for attachment inside the shell of the propellant compartment, the shell serving to bear external stresses. The method of suspension depends on the shape of the tank and the arrangement of the structural elements in the propellant compartment shell. Suspension tanks are justifiable only in rockets with pump-feeding of the propellants. These tanks are made of thin sheets of metal with bosses in places of attachment.

SUSTAINER ENGINE. The main engine of a rocket.

SYNCHRONOUS SATELLITE WITH ELLIPTIC ORBIT. An artificial Earth satellite moving in an elliptic orbit with a period of one day or a submultiple part of a day. In the case when the satellite's period is one day, its apogee will always be over the same point of the Earth's surface. If the satellite's period is 0.5 day the apogee is alternately over two points. By varying the orbit inclination, the apogee width and the launching time of the satellite, it is possible to place the orbit over the required regions of the Earth. In a highly-elliptic orbit the satellite is in the apogee region during most of the time. When the period is one day, the apogee height is 60,000—70,000 km; when the period is 0.5 day, 30,000—40,000 km. Injected into near-synchronous elliptical orbits with a period of 12 h have been the satellites *Molniya-1*, *Cosmos-174* and *Cosmos-260*.

SYNODIC PERIOD of a planet. The interval of time between successive returns to the same position with respect to the Sun of a planet in its apparent motion around the Sun, as seen from the Earth. The synodic MONTH is the average period of recurrence of the phases of the Moon.

SYSTEM INTEGRATION TEST. A series of operations carried out in the maintenance area and launch site for checking the operation of all the systems, assemblies and units of the space vehicle and ground support equipment. PRE-LAUNCH PREPARATION, launch and flight of the spacecraft are simulated on ground when conducting these tests, use being made of special check-out and launch equipment.

SYSTEM OF RADIO COMMUNICATIONS VIA MOLNIYA-1 SATELLITE. The first Soviet system of radio communications and exchange of TV programmes via an ACTIVE RELAY STATION installed on the *Molniya-1* communications satellite. This satellite was sent into an elliptic orbit (with an apogee, after correction, of 39,957 km and a perigee of 548 km) greatly elongated above the Earth's Northern Hemisphere and having an inclination of 65.1°, the satellite's period of revolution around the Earth being 12 h (see diagram). The ground stations of the system of radio communications via the communications satellite are linked by means of cable or radio relay lines with

long-distance telephone exchange offices, telegraph and TV centres. The exchange of white-and-black and colour TV programmes, as well as two-way multi-channel telephone, telegraph and phototelegraph communications between any point of the Soviet Union and many countries of Europe and Asia has been made possible for 9 h every day. In particular, daily two-way communications is maintained between Moscow and Vladivostok. The 40-W transmitter of the relay station emits radio signals via a directional parabolic antenna. The width of the antenna DIRECTIVITY PATTERN is such as to cover the entire surface

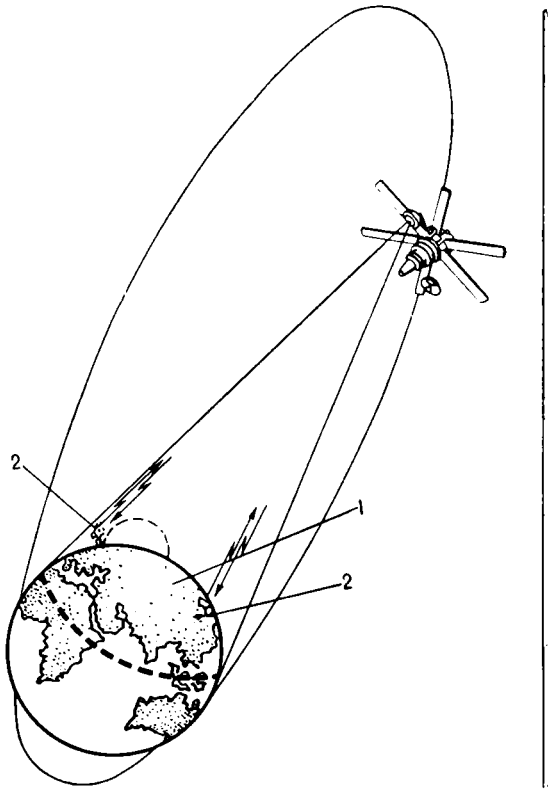


Diagram of radio communication via *Molniya-1* satellite:
1—zone of radio vision (borders shown in dotted line); *2*—ground-based radio stations.

of the Earth within sight of the satellite. As of May 1, 1969, 12 *Molniya-1* satellites have been put into orbit.

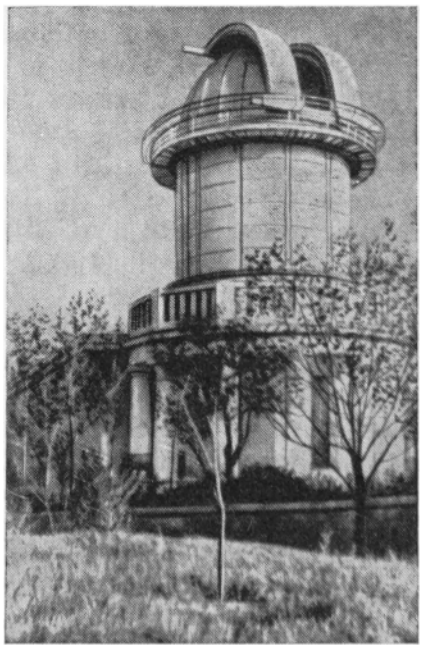
SYSTEM OF SPACECRAFT CONTROL. A set of automatic or semi-automatic (providing for the controls being taken over by the crew) devices that keeps the motion of the spacecraft within specified limits, i.e., maintains the motion, pre-selected or chosen at any moment by the control system, for fulfilling the given mission (reaching a certain planet, rendezvous with another spacecraft, etc.). Control systems differ according to whether they control the motion of the centre of mass of the spacecraft or its angular motion. The latter systems are subdivided into systems of ANGULAR STABILIZATION and systems of ORIENTATION. The main components of most of control systems are the SENSING ELEMENTS, CONVERTING DEVICES and ACTUATORS. See FLIGHT CONTROL.

T

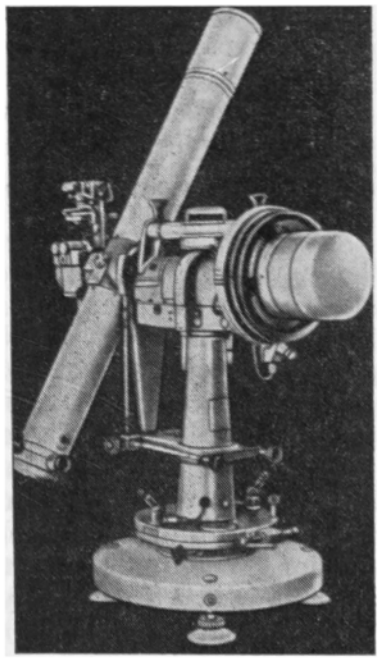
TAKE-OFF WEIGHT. The weight of a rocket when it takes off from the launching pad. The take-off weight of a stage of a multi-stage rocket is the weight at the moment when its engine is started (if this takes place after the stages are separated), or the weight at the moment of separation (if the engine is engaged prior to the separation of the previous stage).

TELEMETRY PICK-UPS. Measuring devices mounted on the rocket and rocket engine for checking the operation of units and systems in flight. The engine telemetry pick-ups are used for measuring the temperature of fluids and structural elements, pressures, vibrations, revolutions per minute of the turbopump, angles of turn of controls and actuators, tracing the passage and execution of commands, etc. The information obtained is converted into electrical signals that are transmitted by radio to ground stations.

TELESCOPE. An astronomical optical instrument which increases the apparent angular width of celestial objects or of distances between them, increases the density of light energy coming from celestial bodies and directs



Solar tower (accommodating a solar telescope).



Zenith telescope.

it into the receivers of radiation, such as eye (in visual telescopes), photographic plates, spectrographs, photometers, cathode-ray tubes, or image converter tubes. It serves also for sighting of celestial bodies with the aim of determining their positions in the CELESTIAL SPHERE. Telescopes are classified into refractor-type (using lenses), reflector type (using mirrors), and refractor-reflector type (using both lenses and mirrors, e.g., meniscus telescope, Schmidt telescope). See also RADIOTELESCOPE.

TELESCOPIC HYDRAULIC JACK. A multi-stage hydraulic jack made up of several hydraulic cylinders inside one another. At the establishment of a pressure within the working volume, the hydraulic cylinders move out in succession and provide a considerable operational stroke of the jack. Telescopic hydraulic jacks may be with direct or direct-and-reverse pressure chambers; the latter are capable of developing forces acting in opposite directions. Telescopic hydraulic jacks are used for lifting ERECTOR arms and gantries into vertical position.

TELEVISION EQUIPMENT of meteorological satellites. The TV cameras and transmitters of a meteorological satellite, which permit observation of the cloud pattern. Use is generally made of wide-angle cameras which, at orbital heights of about 700—1000 km, provide pictures covering a square with a side of the order of 1000 km. To obtain greater coverage, it is common practice to have the satellite carry several cameras. Thus, the satellites *Cosmos-122* and *ESSA* carried 2 cameras each. The TV system can operate either in the "memory" mode, recording the TV pictures on magnetic tape and then relaying them to the Earth when the satellite comes within the radio line of sight of the ground stations, or in the "live" mode, relaying the pictures continuously to the Earth. In the latter case, the TV information can be received by any ground station equipped with suitable receiving equipment as soon as the satellite passes above it. To permit the use of simpler receivers, the TV information is relayed at a low rate.

TELEVISION SYSTEM. A space-borne system designed to take pictures of celestial bodies (the Moon and planets) and to transmit them to the Earth. The TV system consists of a photocamera, in some cases with several lenses (of different focal length), a device for on-board processing the photographed film, and a TV camera to transmit the pictures from the film (usually by their scanning). The TV system permits to obtain high-quality pictures of other celestial bodies from a spacecraft at a great distance from the Earth. This is achieved by sufficiently slow scanning of film pictures through the radio channel which essentially narrows the frequency band of the video-signal and extends the range of radio communication. For example, the resolution of the TV system installed on the Soviet automatic interplanetary station *Zond-3* is 1100 lines; the frame time of 34 min was selected to suit the operation at interplanetary distances.

TEMPERATURE CONTROL SYSTEM. A set of devices used for maintaining a pre-set temperature of the equipment, structural elements and gas inside a spacecraft. The system usually consists of sensors for measuring the temperature at certain points on board; electronic units that generate the temperature-control signals; actuating elements directly affecting the thermal processes; a radiating surface for dissipating the excessive heat released within the spacecraft; a surface coating applied to the outside of the spacecraft and having a specified optical coefficient; and screen-insulation. Simplest temperature control systems transfer the heat from inside the spacecraft and equipment to the outer radiating surface via thermal conductivity of the structural elements, or by forced gas circulation in sealed compartments. More complex systems employ a HYDRAULIC CIRCUIT to transfer the heat from the sources of generation to the outer radiating surface of the spacecraft. The

actuating elements of a system of temperature control are mechanically operated louvres that open or close the radiating surface and hydraulic or gas valves that adjust the circulation of coolant flowing through the hydraulic circuit or that of the gas inside the spacecraft. Besides active control of temperature in the spacecraft, wide use is also made of so-called passive means of keeping individual structural elements and equipment at a pre-set temperature. These include: application of a shielding layer of heat-insulating material to a section of spacecraft surface and to outer structural elements and equipment on board; special processing of the outer surfaces for obtaining a specified optical coefficient of the latter, etc. (see TOTAL EMISSIVITY, RADIATION ABSORPTION FACTOR).

TEMPERATURE OF UNDERLYING SURFACE. The temperature of the Earth's surface determined by measuring the Earth radiation in the atmospheric water vapor windows with the aid of meteorological Earth satellites. The determination of the temperature of the underlying surface is based on its close association with the Earth radiation, since the transformation of the radiation by the atmosphere in the water vapor windows is negligible (provided there are no clouds). Usually use is made of water vapor windows in the spectral region of 8—12 μ or 3.5—4.2 μ wave-length; in order to eliminate the influence of the Earth's atmosphere, use is made of empirical diagrams that associate the difference between the radiation temperature measured by means of artificial Earth satellites and the temperature of the underlying surface with the absolute value of its radiation temperature. The precision of such a method can be as high as 1°—2°.

TERESHKOVA (Nikolayeva-Tereshkova), Valentina Vladimirovna (born 1937, near Yaroslavl). The world's first spacewoman. Hero of the Soviet Union. Member of the CPSU since 1962. At the age of 16 went to work at the Yaroslavl Tyre Factory, and later at a textile mill. In 1960 graduated from the correspondence course of a secondary technical school of the textile industry. Graduated from the Air Force Engineering Academy in Moscow in 1969. Her road into space began with training in parachute jumping at the Yaroslavl Air Club; she has 126 parachute jumps to her credit. On June 16—19, 1963, the *Vostok-6* which she piloted in a group flight with V. F. BYKOVSKY, orbited the Earth 48 times covering about 2,000,000 km in 71 h.

TERMINAL PATH OF APPROACH (docking) of spacecraft. The part of APPROACH of spacecraft along which their own dimensions and the distance between them are commensurable. The final path of approach imposes certain limitations on the angular attitude of the spacecraft, making it necessary, for example, to position the spacecraft so that the ends being joined face each other. This makes the terminal approach of spacecraft very difficult and calls for the use of several auxiliary rocket engines so as to move the spacecraft in different directions without changing their angular attitude.

TERRESTRIAL MAGNETISM. The magnetic field of the Earth and near-Earth space; the section of geophysics that deals with the geomagnetic field and pertinent geophysical processes on the Earth and in the UPPER ATMOSPHERE. The effect of the magnetic forces in the near-Earth space and in the accessible depths of the Earth is detected by: the moment of the forces applied to freely

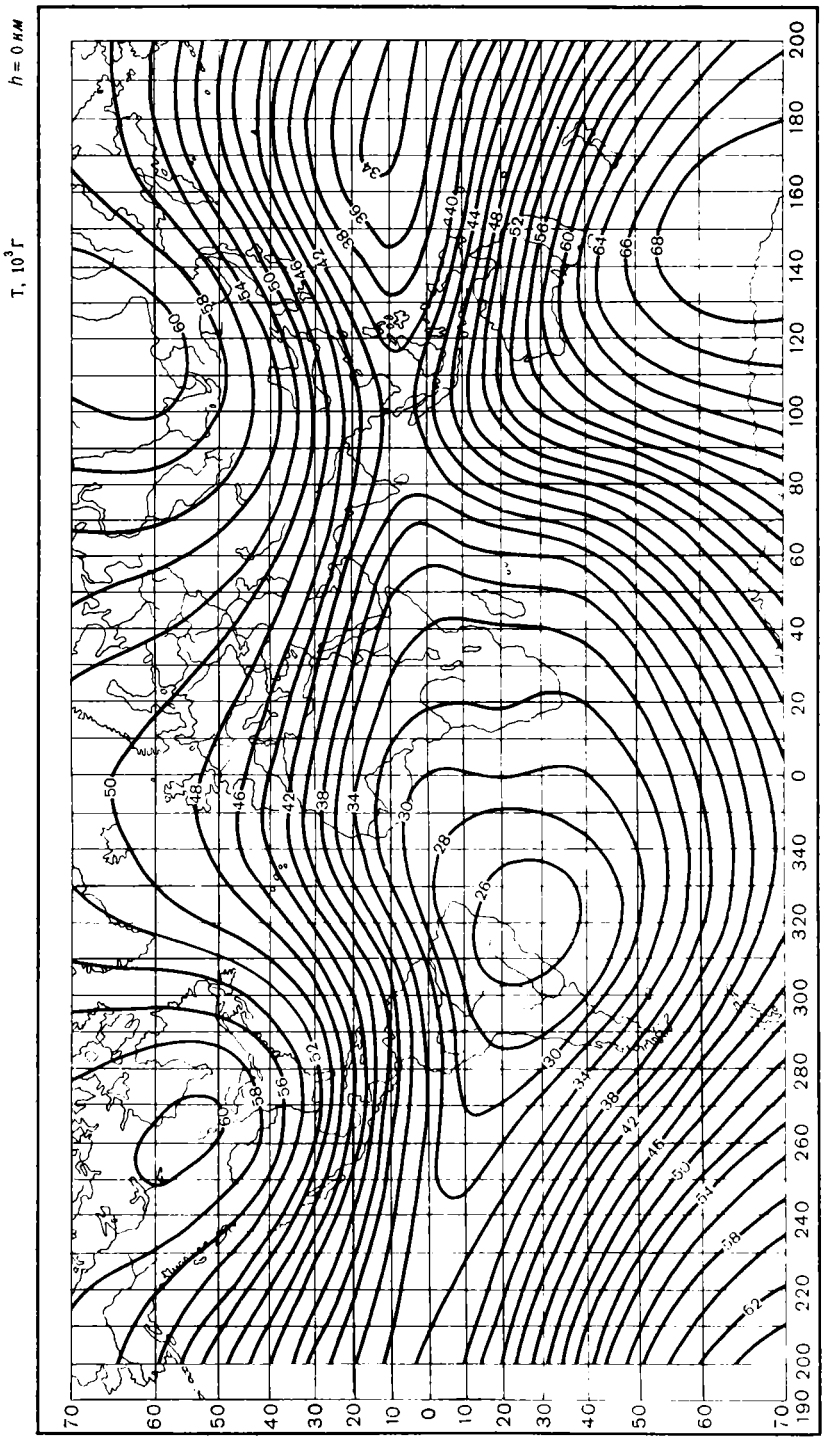
suspended magnetized needles; the electromotive force induced in the rotary coils of a conductor; the frequency of free precession of protons in liquids; the splitting of the Seemanian sublevels in alkali metals; the deflecting effect on the charged particles of cosmic radiation; the effect of polarization of radio waves, etc. The Earth's magnetic field is governed by the influence of constant sources located within the Earth, which undergo only slow secular variations, as well as the effect of external sources depending on the geographical latitude, local time and SOLAR ACTIVITY. Accordingly, a distinction is made between the main and varying magnetic fields of the Earth. The nature and origin of these fields are different, but they are closely interrelated.

Main geomagnetic field. The magnetic field vector at any point of the Earth's suface is specified by its intensity H and its direction relative to the horizon (angle of magnetic inclination I) and to the geographic meridian (magnetic declination D). To the first approximation, the variations in the intensity and direction of the geomagnetic field are similar to those around a uniformly magnetized sphere or magnetic dipole. Actually the distribution of the intensity of the magnetic field over the Earth's surface is very complex. It is represented by means of special maps which indicate the course of the field components x (along the meridian), Y (along the parallel), the vertical component z of the total intensity T and its directions in space D, I (see Fig., p. 452). On the Earth's surface there are 6 regions where the dipole character of the field is distorted over large areas; these are the major anomalies, e.g., the positive anomaly in East Siberia and the large Brazilian negative anomaly. An even greater difference from the dipole distribution is observed in regional and local anomalies.

Besides the cartographic representation of the magnetic field, scientific investigation makes use of spherical harmonic analysis proposed by Gauss. The part of the field of a dipole character on the Earth's surface comprises 87% of the total field. The sum of all the higher harmonics equals approximately 13%. Only harmonics of very high orders are associated with the upper parts of the Earth's crust .The main uniform part of the field as well as the field of low harmonics is caused by electric currents in the liquid conducting core of the Earth. On departure from the Earth's surface the intensity of the dipole magnetic field decreases inversely to the cube of the distance and the harmonics of higher orders decrease even faster. The percentage of the dipole field, that comes from internal sources, in the total field at various heights is given in the table below.

h, km	200	400	1000	2000	$1R_E$	$2R_E$	$3R_E$	$4R_E$
%	87.5	87.7	89.4	90.9	94.8	96.3	97.7	98.6

In solving a number of problems, the geomagnetic field can be assumed to be a dipole field, with due consideration to the approximation indicated above.



Map of total intensity T of geomagnetic field at Earth surface.

The geomagnetic field that comes from internal sources undergoes secular variations, the main features of which are the decrease in the magnetic moment of the Earth at a rate of 20 γ annually and the systematic westward drift of the field at a rate of 0.15° annually. It is believed that the secular variations are attributable, in the main, to the processes of change in the intensity and topology of the electric current systems in the conducting core of the Earth, which are the main source of the Earth's magnetic field proper; therefore investigation of the secular variations is one of the most important means of studying the internal structure of the Earth. Secular variation leads to the re-drawing of the magnetic maps; these maps have to be corrected, furthermore, because over great areas, especially those occupied by the oceans, the magnetic field is not known well enough. It is for this reason that it was necessary to carry out a world-wide magnetic survey. In 1964 with the aid of the *Cosmos-26* and *Cosmos-49* satellites 75% of the Earth's surface was surveyed. As a result, it has become possible to define more accurately the coefficient of the Gauss series and to adopt an international analytical model of geomagnetic field.

The investigations carried out in the last few years have shown that the SOLAR WIND, the constantly flowing solar plasma, distorts the magnetic field, constricting it on the sunlit side and sweeping away the lines of force of the polar regions on the dark side, thus forming the magnetic trail of the Earth with a length of more than 80 Earth radii (see MAGNETOSPHERE). The trapped radiation (chiefly protons of the outer radiation zone) comprises the constant external source of the magnetic field. The effect of these protons is equivalent to that of the circular current whose intensity at the time of magnetic stability is 20—70 gammas at a distance of 3.5 Earth radii or 10—30 gammas on the surface of the Earth. Another constant feature of the magnetosphere is its magnetohydrodynamic trail in the outer space, i.e., the impact front separated from the magnetosphere by a turbulent intermediate region.

Varying magnetic field. The Earth's magnetic field is constantly undergoing changes which are continuously recorded by special magnetic observatories. At the time of the greatest stability, solar and lunar diurnal geomagnetic variations of a daily range of 40 and 10 gammas, respectively, are observed; they are caused by electric currents in the *E* layer of the IONOSPHERE. In the polar regions the field is never stable. Variation of the field during MAGNETIC STORMS that occur principally in these regions are described by polar current systems; its main feature is the electrojets coinciding with the auroral zone in the zenith and the region where the lines of force of the external limits of the outer radiation zone cross the Earth's surface. Magnetic disturbances extending throughout the Earth are called world-wide magnetic storms. They are accompanied by an increase in the intensity of auroral displays, a change in the height and density of the ionized layers, leading to impairment of communication on short waves due to Earth current storms.

World-wide magnetic storms sometimes begin suddenly and sometimes, gradually. Storms of the first type are most often associated with solar chromospheric flares and originate 24—48 h after the flares. Moderate mag-

netic storms are likely to recur after 27 days. Storms display cycles with a period of ~11 years, the same as the cycles of solar activity. According to modern concepts, magnetic storms are caused by corpuscular streams ejected from limited regions of solar activity, superposed on steady solar winds. On reaching the Earth the stream constricts the magnetic field, giving rise to the initial phase of the magnetic storm. In the polar regions substorms are developed, while within the magnetosphere an electric current ring appears at a distance of about 3.5 Earth radii, leading to a decrease of the field during the main phase of the magnetic storm. The mechanism of formation of this ring is not as yet well understood. The storm lasts several days during which diurnal variations in the disturbance of the field are observed; the horizontal component increases in the evening and decreases in the morning. Gradually the field returns to the undisturbed state. An important part in the development of magnetic disturbances and aurorae is attributed to the processes in the magnetic trail of the Earth on the dark side. Besides the regular and irregular disturbances described above, short-duration variations of different frequencies and characteristic classes are observed on magnetograms. Their origin is associated with the processes occurring in the radiation zones and boundary regions of the magnetosphere. Magnetic variations of all the above-indicated classes induce electric currents in the Earth which produce the internal part of the field due to external sources.

The lines of force of the geomagnetic field extending over tens of thousands of km in outer space determine the physical properties of the near-Earth space and the character of many processes occurring in the higher layers of the atmosphere. They play an outstanding part in the mechanism of the effect of the solar corpuscular radiation on the Earth. Retaining a rather constant orientation relative to the Earth's surface at considerable heights, the magnetic field is made use of in sea navigation, air navigation, deceleration, manoeuvring, and orientation of spacecraft. The effect of the magnetic field is taken into account when designing attitude-controlled spacecraft. Magnetometric methods are effective in forecasting the conditions of radio-wave propagation.

TESTING OF ROCKET ENGINE. The check-out in stands and in flight of the performance and main characteristics of a rocket engine and its assemblies. Mock tests should be distinguished from firing tests. In case of mock testing no propellant is burned (or the working fluid heated) and model fluids are frequently used to check the actuation of various units. Checked, usually partially, during these tests are such characteristics as strength, tightness, and proper functioning of the thrust chambers, gas generators, pumps, automatic systems, etc. The propellant is burned (or the working fluid heated) in case of firing tests. Mock and firing tests are subdivided into exploratory, development captive, routine percentage (or type), special check-out, interdepartmental, and state qualification tests. Various design versions of rocket engine units are studied during exploratory and development captive tests, and the best ones are selected, the functioning and characteristics of the rocket engine and its units are checked, as well as the engine's capacity and service life. These captive tests are brought as close as possible to the

real operational conditions. Tests of liquid-propellant engines are made in more rigorous conditions than the operational ones, the ratio of propellant components, pressure in the combustion chamber and gas generator, temperature of propellant components, inlet pressures and other parameters being chosen in various, including extreme, combinations. At an early stage, the exploratory tests of rocket engines are usually conducted on model (small-size) engines or prototypes.

The routine tests are official captive check-outs of every single production-made rocket engine. Their purpose is to confirm the normal operation of the engine and its units, and to see if the measured characteristics of the rocket engine meet the specification. The percentage (or type) tests are the official acceptance tests of a batch of rocket engines, during which several selected engines are captive tested to check their service life and the conformity of main measured characteristics with the specification. Special check-out tests are held, usually once a year, at rocket engine factories with the view to check in rig if the engine retains a reliability margin by conducting trials under an expanded programme and in conditions differing considerably from the operational ones. The final stage in testing are flight tests that are preceded by hold-down tests of the engine mounted on the rocket. Inter-departmental or state qualification tests (static and flight tests) confirm the completion of engine development and organization of its serial production. Rocket engines are tested on special stands and rigs, in laboratories and test stations.

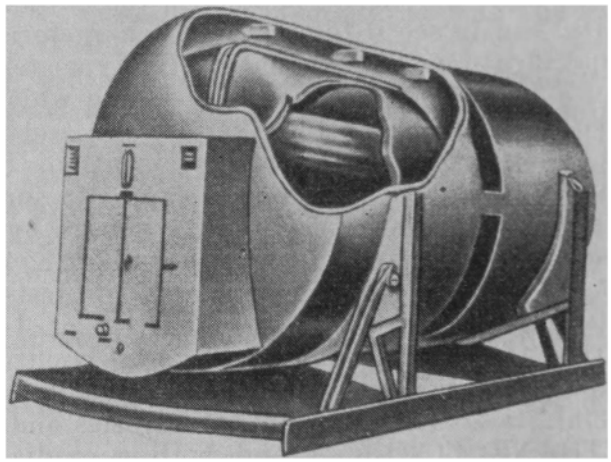
TETRANITROMETHANE, $C(NO_2)_4$. A high-boiling oxidizer for liquid-propellant engines. A colourless, pungent liquid; density, 1.64 g/cm^3 at 20°C; m.p., 13°C; b.p., 125.7°C; extremely toxic; stable, but explosive hazardous. It is moderately corrosive, attacking metals only slightly. Its effectiveness is close to that of NITROGEN TETROXIDE; gives an equal specific impulse, but produces a propellant with a greater density. The chief disadvantages of tetranitromethane by itself are its explosion hazard and high m.p. Solutions of nitrogen tetroxide (20—25%) in tetranitromethane are relatively explosion-proof and have a lower m.p. Tetranitromethane was proposed as propellant in the GDL (1930). It has not come to be used.

THERMAL COVER. A multi-layer sandwich covering in which textile layers are intermittent with sheets of thermal-protective material; this cover is meant for protecting space objects against overheating or overcooling. Frame-mounted covers retain their own shape, whereas frameless covers acquire the shape of the space body on which they are put. Electric heating elements for heating the space body are embedded in the thermal cover; in certain cases special ducts are provided within the cover for circulating hot or cold air. The thermal cover is removed prior to launch. Thermal covers are also used for maintaining a specified temperature of propellant in vehicle tanks and propellant terminals. The cover is made up of cloths between which insulating material—glass fibre or PVC-impregnated fabric—is placed. The individual cloths covering a tank are joined together.

THERMAL ENGINE. An engine in which thermal energy is transformed into useful mechanical energy. All chemical rocket engines are thermal ones, as are nuclear rocket engines which transform nuclear energy into thermal and electrothermal rocket engines.

Thermal insulation of containers

THERMAL INSULATION OF CONTAINERS. Thermal insulation of tanks containing cryogenic propellants serves to decrease evaporation losses. When vacuum insulation is used, the space between the container and its outer housing is evacuated. The efficiency of the insulation depends on the degree of vacuum achieved. Vacuum-powder insulation calls for the space between the container and its outer housing to be filled with porous insulating powders (e.g., santosel or perlite) with very low coefficients of heat



Vessel for cryogenic propellants.

conductivity and then to be evacuated to a level one order lower than that used for vacuum insulation, which is technically easier to achieve. Vacuum and vacuum-powder thermal insulation permit heat transfer by radiation only. Screen-vacuum insulation is more costly, but it prevents the containers from heat transfer by radiation as well. The surface of the containers is covered with a series of shields with low radiating power, e.g., with aluminium foil; layers of heat-insulating fabric are placed between the shields, and the entire insulating space is evacuated. Vacuum-powder insulation makes it possible to decrease evaporation losses, even for liquid hydrogen, to 0.06% in 24 h when the propellant volume in the containers is 2,000,000 l. In a vessel with screen-vacuum insulation such a loss arises in a considerably longer time.

THERMAL OXIDATION of biological wastes in an LSS. A physico-chemical method of mineralizing human and other biological wastes (see BIOCOMPLEX), based on oxidation of organic and decomposition of inorganic compounds in a hot stream of air (600°—900°C). The end products of thermal oxidation are ash and gaseous substances. The ash may contain Ca, K, P, Fe, Mg, and other elements; the gases may contain CO_2, CO, S_xO_y, N_xO_y, N_2, H_2O, etc. Thermal oxidation is a simple method, but it consumes large quantities of power and oxygen. This makes its use reasonable only for mineralization of solid and dehydrated biological wastes that cannot be mineralized otherwise. The use of thermal oxidation is the most feasible in semi-closed LSS.

THERMAL PROTECTION of re-entry body. That part of the external skin of a re-entry body, which is subject to the direct action of aerodynamic heating and serves to hold the temperature of the structural elements and inner medium of the body within permissible limits. Thermal protection is provided primarily by heat-resistant high-strength coatings based on reinforced ceramic or synthetic materials, so that during aerodynamic heating the coating reaches a temperature of fusion, sublimation, or dissociation of its components which are partly carried away by the mechanical action of the air stream sweeping over the coating. A necessary part of the thermal protection is a layer of low density heat-insulating material applied under the external ablative layer to prevent transfer of the heat to the structural members and inside the re-entry body.

THERMIC SOUNDING OF ATMOSPHERE. A method of determining the vertical profile of air temperature, based on data of spectral measurements of EARTH RADIATION. Best developed is the method of thermic sounding of atmosphere, based on data of radiation in the region of 15μ of carbon dioxide band (in the case of radiation in the carbon dioxide bands, the problem is simplified because its relative volume concentration may be regarded as constant); by measuring radiation in 5—6 regions of the spectrum of the 15μ band with resolution of the order of 5 cm^{-1}, it is possible to obtain approximate information on the vertical temperature profile. Promising is the possibility of interpretation, for the purpose of thermic sounding of atmosphere, of data of measurements in the 4.3 μ band of carbon dioxide and in the micro-wave region of the spectrum.

THERMIONIC CONVERTER. A device for obtaining electrical energy directly from heat, using the process of emission of electrons from a hot cathode into the inter-electrode space that is either evacuated or filled with plasma of alkaline metals (vacuum or plasma diode). May be used as a component of space power supply station.

THERMOCHEMICAL ROCKET ENGINE. See CHEMICAL ROCKET ENGINE

THERMODYNAMIC ANALYSIS OF ROCKET ENGINE. Estimation of thermal processes of transformation of the working fluid in the combustion (heating) chamber and the nozzle of a rocket engine. These processes are related to heat release during combustion (decomposition) of the propellant, or to heating of the working fluid, e.g., by release of nuclear energy, or to transformation of heat into the kinetic energy of jet efflux. This analysis determines the theoretical parameters of the working fluid in the combustion (heating) chamber and nozzle: composition, pressure, temperature, density, velocity, pressure specific impulse, etc., as well as thrust and specific impulse. The thermodynamic analysis takes into consideration the dissociation of the working fluid components in the combustion (heating) chamber and their recombination in the nozzle. In most cases the thermodynamic analysis is made assuming the chemical and physical (power and phase) equilibrium of the working fluid components. Examined in the latter case is an equilibrium distribution of energy into different types of molecular motion (translational, rotational and vibrational), equilibrium of various phases in MULTI-PHASE FLOW, etc. In some cases the thermodynamic analysis is made assuming the constant chemical composition of products of combustion

or heating during their flow in the rocket engine nozzle, which is an assumption of an extreme case of chemical unequilibrium ("frozen" flow). Some analyses are made on the assumption that the gas in the nozzle expands to a certain temperature with the gas components being in chemical equilibrium, while a "frozen" flow is observed below this temperature. A more accurate thermodynamic analysis shall take into account the kinetics of chemical reactions, the time of relaxation of vibrational energy, etc.

THERMO-ELECTRIC GENERATOR. A unit for directly (non-magnetically) converting thermal energy into electricity by means of the thermo-electric effect occurring when semiconductors or junctions of dissimilar metals develop a thermo-electromotive force caused by a temperature difference in them. Such a unit can power an electric rocket engine or space-borne equipment. The generator may be heated by a nuclear reactor, NUCLEAR ISOTOPE BATTERY or other source. Cooling is achieved by heat radiation into space.

THERMONUCLEAR ROCKET ENGINE. A hypothetical rocket engine in which the source of energy is the thermonuclear process, i.e., the reaction of the synthesis of heavier atomic nuclei from light ones (e.g., helium from isotopes of hydrogen).

THERMOPAUSE. The region of the UPPER ATMOSPHERE above the THERMOSPHERE, characterized by transition to constant temperature with height. In the thermopause the absorption of solar HF radiation is low, so that its intensity and, therefore, the average heat influx per atmospheric particle changes slightly with altitude. Constancy of temperature indicates the absence here of any noticeable sources of thermal energy besides solar radiation. Therefore, with the appearance at great altitudes of additional heat sources (e.g., due to absorption of magnetohydrodynamic waves, or very soft particles during aurorae) one can no longer speak of the thermopause. The temperature of the thermopause and the concentration of atmosphere components in it vary sharply depending on the level of solar and geomagnetic activity; they also fluctuate diurnally and annually.

THERMOSPHERE. The region of the UPPER ATMOSPHERE at altitudes of 90 to 200—400 km, where the main processes of absorption and conversion of the energy of solar short-wave (UV and X-ray) radiation take place causing a rise in the temperature of neutral atmospheric particles from $\sim$200° to 500°—2500°K as the altitude increases, depending on time of day and solar activity. Absorption of quanta of solar UV radiation with wave-lengths less than $\sim$1000 A causes ionization of atmospheric components, i.e., the formation of the IONOSPHERE. Hence, the main regions of the ionosphere (E, F_1, F_2) lie within the thermosphere.

In addition to ionization, also characteristic of the thermosphere is dissociation of oxygen and nitrogen molecules, which leads to vertical variations of atmospheric composition. Above 300 km monatomic oxygen predominates. The molecular weight of the air drops from 29 at lower boundary of the thermosphere to 16 at its upper boundary. Heat transfer in thermosphere is determined mainly by thermal conductivity of the gases.

Triple collisions in the lower part of thermosphere cause recombination of oxygen atoms into molecules. Thus, in the thermosphere, both processes

of recombination of ions (disappearance of ionization), and other photochemical processes, resulting, in particular, in the appearance of luminescence of the upper atmosphere itself both in the day time and in the night time, occur simultaneously.

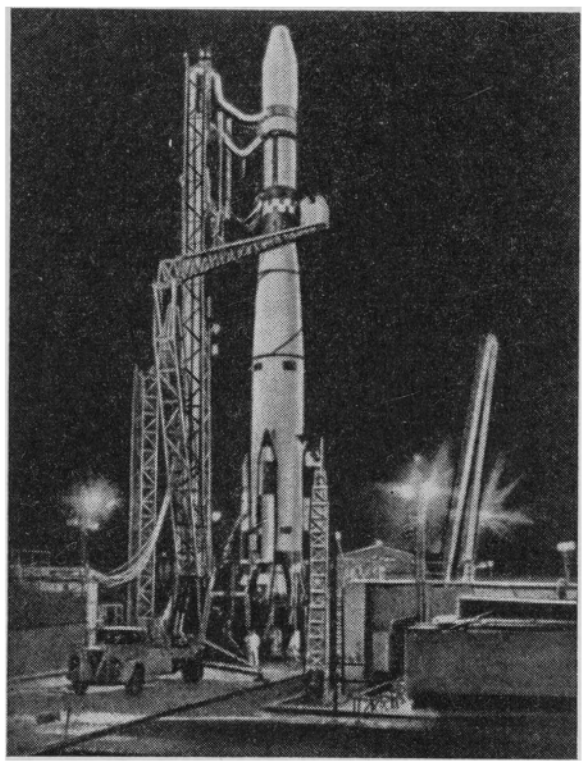
Throat section of nozzle

THERMOSTATIC CONTROL OF PROPELLANT. Heating or cooling of a propellant to maintain its temperature within a specified range. This is essential in order to retain the required chemical activity and physical properties, such as density and viscosity. Besides, in many cases the difference in the temperatures of oxidizer and fuel (for high-boiling propellants) must be within specified limits. Thermostatic control is performed by heat exchangers whose temperature is maintained by cooling and heating machinery.

THIRD COSMIC VELOCITY. The minimum initial velocity which an object must acquire when starting at the Earth's surface to overcome the attraction of the Earth and that of the Sun and to leave the solar system. At the surface of the Earth the third cosmic velocity is $\sim$16.7 km/s.

THIXOTROPIC PROPELLANT. A jelly-like propellant that becomes liquid under the action of pressure, which makes it possible to use it for liquid-propellant engines.

THOR. A series of USA launch vehicles that use the *Thor* intercontinental ballistic missile as the 1st stage. The launching weight ranges from 52 to 70 t, and the total length from 25 to 28 m. The 1st stage uses a liquid-propellant engine developing a thrust of 78 t and firing LOX and kerosene. The *Thor-Delta* modification is a 3-stage launch vehicle whose 2nd stage, the *Delta*, has a liquid-propellant engine using nitric acid and dimethyl hydrazine to develop a thrust of 3.5 t. The 3rd stage uses a solid-propellant engine. *Thor-Agena D* is a 2-stage launch vehicle, *Agena D* being the 2nd stage. *Thorad-Agena* (*TAT-Agena*) differs in that the 1st stage is assisted by 3 solid-propellant boosters. The payloads launched into a low satellite orbit range for different modifications from 220 to 600 kg and above. *Thor* has been used to launch *Explorer*, *Tiros*, *Discoverer*, *Telstar*, *Early Bird*, and other spacecraft.

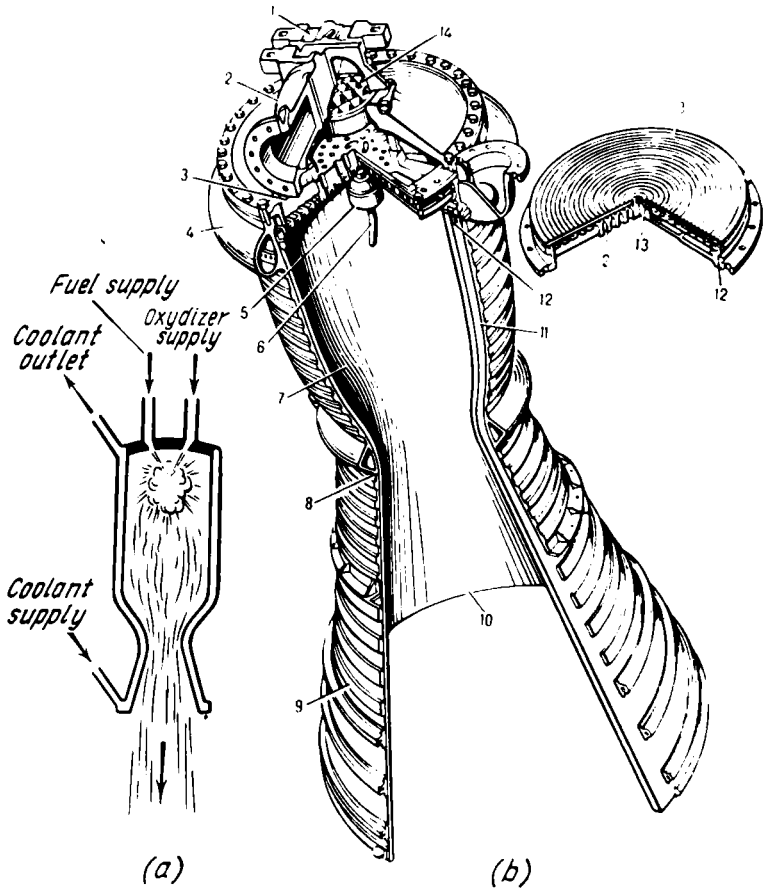


American launch vehicle *Thorad-Agena*.

THROAT SECTION OF NOZZLE. The section in which the mean velocity of gas is equal to the local speed of sound. For flow of an ideal gas without

chemical reaction, heat input or friction, the throat section coincides with the minimum (in area) section of the nozzle. Owing to the occurrence of irreversible processes in the flow, the throat section is caused to shift into the expanding portion of the nozzle (in the direction of flow). In engineering practice this term is used for the minimum section of the nozzle.

THRUST CHAMBER OF LIQUID-PROPELLANT ENGINE. The main unit of a liquid-propellant engine. It consists of a combustion chamber with an



Thrust chamber of liquid-propellant engine: (*a*) schematic diagram; (*b*) thrust chamber of *RZ-2* liquid-propellant engine (Great Britain) firing liquid oxygen and kerosene, which powers *Blue Streak* rocket.

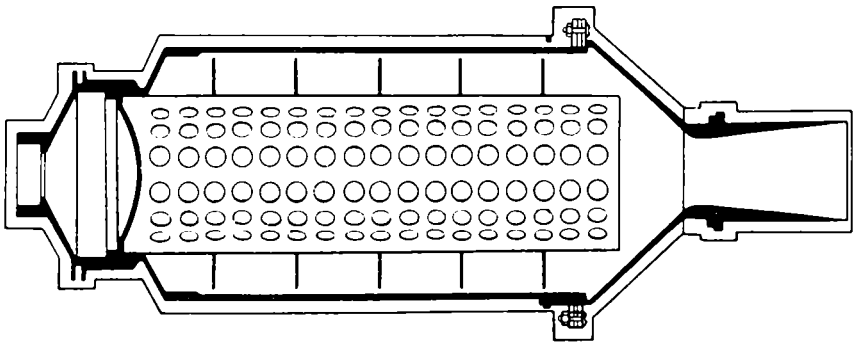
1—thrust chamber gimbal; *2*—liquid oxygen supply; *3*—mixing system; *4*—kerosene supply pipeline; *5*—ignitor cartridge; *6*—ignitor electric lead; *7*—combustion chamber; *8*—throat section of nozzle; *9*—ribs for imparting strength and rigidity to thrust chamber; *10*—jet nozzle; *11*—chamber walls composed of tubes that pass kerosene coolant; *12*—kerosene supply; *13*—starter fuel supply; *14*—grid for streamlining the flow of liquid oxygen.

injector in it and a nozzle. The combustion chamber may be cylindrical, conical or spheric (pear-shaped) in form. Most combustion chambers have a form close to cylindrical (except for the injector) and are designed either as interconnected shells (the internal fire wall and the outer jacket), or as thin-

walled pipes welded together and reinforced externally by structural bands. The internal and external shells are joined by high-temperature brazing through ribs formed on the inner wall, or through thin-wall corrugated spacers, or by other means. The channel between the shells or the internal channels of the pipes are used for pumping the liquid that cools the inner wall.

When external cooling is used, the inner wall is made thin, otherwise its temperature on the hot side will be excessively high. Such a wall operates in heavy thermal conditions with a high pressure difference between the cavity of the cooling liquid and that of the combustion products. The outer shell is the load-carrying one. The manifolds, through which the coolant is supplied into the channels between shells, are situated beyond the nozzle throat and serve additionally as rigidity members. The part adjacent to the exhaust end of the nozzle, which is subject to lower thermal load, has sometimes no outer shell, cooling being achieved by the liquid flow between the fire wall and the corrugated spacer. If this part of the nozzle is not liquid-cooled, the corrugated spacer is absent, too.

THRUST CHAMBER OF ROCKET ENGINE. The main unit of a rocket engine which creates the reactive force by ejecting a working fluid. A thrust chamber consists of a combustion chamber and a nozzle, and is usually integral. The



Thrust chamber of *РД-09* hybrid rocket engine.

line separating the combustion chamber from the nozzle is symbolical. The combustion chamber is the main part of the thrust chamber. In liquid-propellant engines the propellant is injected into the combustion chamber through an injector which is its component part. In a solid-propellant engine the entire propellant charge is placed in the combustion chamber. High pressures, reaching tens and hundreds of at, develop in the combustion chamber during the engine operation. Gas temperature in the combustion chamber is 2000°—4500°C.

THRUST COEFFICIENT. The ratio of the thrust produced by the thrust chamber to the product of chamber pressure (to be more precise, stagnation pressure in the throat) by the throat area. A dimensionless parameter characterising the nozzle operation. Thrust coefficient diminishes with an increase of losses in the nozzle. It grows with an increase of the nozzle expan-

sion ratio. The thrust coefficient is usually equal to 1.2—2. It is also equal to the ratio of the thrust cha mber specific impulse to the pressure specific impulse.

THRUST DIE-AWAY. The burning of a rocket engine from the command for engine cut-off till the actual thrust termination. The thrust die-away complicates the achievement of required accuracy in the rocket's final velocity at the end of its powered flight, and therefore attempts are made to reduce the effect and, especially, its dispersion. To do so, liquid-propellant engines are sometimes cut off in steps, through an intermediary stage, or the propellant contained in feed lines of the rocket engine is blown away after the propellant supply is stopped. Measures are taken to ensure an abrupt stop in the propellant feeding, etc. To reduce the thrust die-away in solid-propellant engines, gas pressure is dropped in the combustion chamber, which results in a quick termination of the propellant combustion.

THRUST DUTIES of a solid-propellant engine. Time dependence of thrust is usually characterised by ignition retardation, transition to rated duty, quasi-stationary duty, pressure drop, and thrust die-away. The quasi-stationary stage is subdivided into thrust augmentation (progressive combustion), permanent thrust (neutral combustion) and thrust decrease (regressive combustion). Thrust changes do not necessarily have to be monotonous. The time dependence of thrust is determined mainly by time changes in the combustion area of the solid-propellant grain and the increase in the nozzle throat area (due to burnout of the walls). The duration of each thrust duty depends on the specific application of the solid-propellant engine. Usually the quasi-stationary duty comprises more than 95% of the entire time of engine operation.

THRUST OF ROCKET ENGINE. The force developed by the engine. It is equal to the reaction force minus the product of ambient (atmospheric) pressure by the nozzle exhaust area.

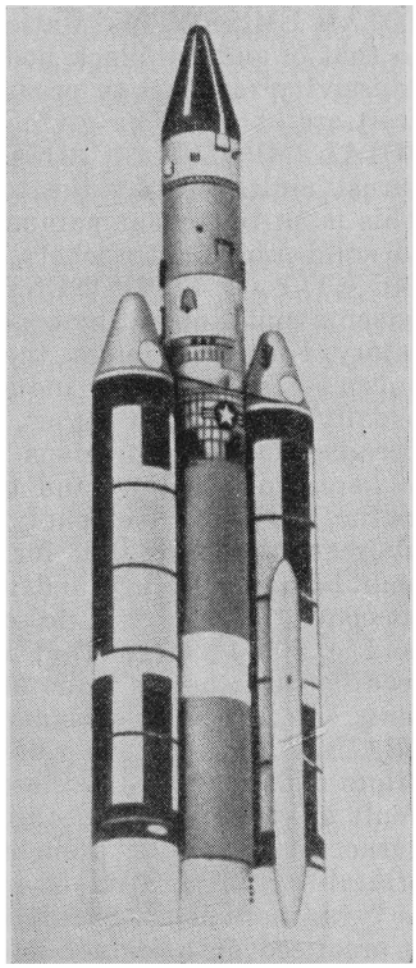
TIKHOMIROV, Nikolai Ivanovich (1860—1930). Chemical engineer, organizer and head of the Gas Dynamics Laboratory, Soviet pioneer of missiles propelled by smokeless powder. He studied this problems since 1894. In 1912 submitted a project which received positive conclusion by a panel of experts headed by N. Y. Zhukovsky in 1916. In 1921, having received funds and premises in Moscow from the military authorities, organized a laboratory with shops (17 lathes), which was named after him. In Leningrad he directed work in developing smokeless grain powder with a solid solvent; test rocket firings were also carried out in Leningrad. By 1927 the powder was created and the complete laboratory was moved to Leningrad. After the first successful rocket flights Tikhomirov's reaction laboratory was greatly expanded and renamed into the GDL. A crater on the far side of the Moon has been named after N. I. Tikhomirov.

TIME. Measurement of time is based upon the rotation of the Earth and its revolution round the Sun. *Sidereal time* is defined as the hour angle of the VERNAL EQUINOX (one revolution of the equinox equals one sidereal day); *solar time* is called *apparent* if the apparent Sun motion is the reference. In everyday life use is made of *mean solar time* where the mean solar DAY is the average of all solar days of a year. The difference between the mean and the true solar days, which can be as large as 16.4 min., is called EQUATION OF TIME.

Time measured from midnight at the point of observation depends on its geographical longitude and is referred to as *local time*. The local mean solar time on the zero (Greenwich) meridian is called *universal time*. The entire globe has been divided in longitude into 24 zones and all points in each zone live according to the mean solar time of the particular zonal mean meridian. Zonal or standard time in adjacent zones differs by 1 h. Standard or *daylight saving time* is 1 h ahead of the zonal time throughout the year (or during the summer season). Standard time in the 2nd hour zone where Moscow is located is called Moscow time.

TIROS. A series of American meteorological satellites whose name is made up of the initial letters of the following words: *T*elevision and *I*nfra-*R*ed *O*bservation *S*atellite. 10 satellites of the *Tiros* type were launched from 1960 to 1965. In 1966 they were substituted by *ESSA* satellites. The *Tiros* satellites carried TV instruments for studies of the cloud pattern and actinometering instruments.

TITAN. The name of a series of American launch vehicles designed on the basis of the *Titan* intercontinental ballistic missile. *Titan-2*, a 2-stage vehicle, was used for launching the *Gemini* spaceships. Its take-off weight is ~150 t; total length, ~33 m. The 1st stage has 2 liquid-propellant engines with a total thrust of 195 t; the propellant used consists of NITROGEN TETROXIDE and AEROSENE-50. The 2nd stage has a liquid-propellant engine with a thrust of 45 t (same propellant). *Titan-3C* is a 4-stage launch vehicle; it differs from *Titan-2* in that it has an additional booster consisting of 2 units with solid-propellant engines whose total thrust is 900 t; this booster is the 1st stage. The 4th stage, *Transtage*, weighing ~13 t, has a liquid-propellant engine with a thrust of 7.2 t, which burns nitrogen tetroxide and aerosene-50 and is restartable in flight. The take-off weight of *Titan-3C* is ~630 t. The payload



American launch vehicle *Titan-3C*.

sent into low satellite orbit is ~10 t. Its flight tests were used for launching of groups of communication and other Earth satellites.

Titov

TITOV, Gherman Stepanovich (born 1935, Verkhneye Zhilino village, Kosikhino District, Altai Territory). Pilot-Cosmonaut of the USSR. Colonel. Hero of the Soviet Union. Deputy of the Supreme Soviet of the USSR. Member of the CPSU since 1961. Graduated from an Air Force school for pilots in 1957. Was an Air Force pilot. Graduated from the Air Force Engineering Academy in Moscow in 1968. On August 6—7, 1961, made the second orbital space flight in the history of mankind aboard the *Vostok-2*. In 25 h the spaceship orbited the Earth more than 17 times, covering a total of over 700,000 km.

TONKA-250. A fuel for liquid-propellant engines. A liquid mixture of the isomers of xylidine $C_6H_3(CH_3)_2NH_2$ (50% by weight) and triethylamine $(C_2H_5)_3N$; an oily, hygroscopic, high-boiling liquid, yellow in colour, with an amine odour; density, 0.84—0.85 g/cm³ at 20°C; it melts in temperature range from —90° to —105°C, and boils from 85° to 215°C. Toxic, stable in the absence of air, noncorrosive. Was extensively used in combination with nitric acid, forming a self-igniting propellant. Developed in Germany in the beginning of the 1940s.

TOTAL EMISSIVITY. Ratio of the radiation intensity of a given surface to that of an ideal black body at the same temperature. The values of total emissivity required to produce the necessary thermal condition in a spacecraft are obtained by giving its surface a special treatment or coating.

TOTAL IMPULSE OF ROCKET ENGINE. The product of the rocket engine thrust multiplied by the total time of its operation, measured in kgf·s. This is an important parameter which is used more frequently with respect to solid-propellant rockets.

TOXICITY OF COMPONENTS of rocket propellants. Many propellant components under operating conditions have a toxic effect, mainly, on the respiratory tract. Therefore the maximum permissible concentration of the poisonous substance in industrial atmospheres during prolonged inhalation, usually expressed in mg/m³, can serve as an index of toxicity. The maximum permissible concentrations are approximately equal to 300 for vapours of kerosene, gasoline, and turpentine; from 20 to 50 for ammonia, diethyl amine and methyl alcohol; 5 for nitric acid and nitrogen tetroxide; 1 for hydrogen peroxide; 0.03 for fluorine and ozone; 0.01 for fluorine monoxide, pentaborane, mercury and lead; as compared to the maximum permissible concentrations for war poison gases: 0.5 for phosgene; 0.3 for hydrocyanic acid; 0.003 for tetraethyl lead. Dangerous concentrations originate more readily when use is made of low-boiling and, especially, cryogenic propellants, i.e., volatile substances.

TRAINER. A simulating device for practicing working habits and training pilots and spacemen, whose training in real conditions is impossible, difficult or economically prohibitive. Trainers for spacemen are ground and airborne. For example, proficiency in performance of operations in spacecraft orbital docking is attained in ground trainers, while the proficiency required to pass from one spacecraft to another during flight along Kepler's parabola is practiced on a trainer mounted in the fuselage of an aircraft. There are

laso various ground trainers for acquiring skill in spacecraft control during landing, monitoring the operation of various space-borne systems, etc.

A small space-borne trainer is used to maintain throughout the whole flight the spaceman's habit of orientation, navigational calculations and spacecraft control which are necessary only at specific moments of the flight (correction of the flight trajectory, docking in orbit, landing on other planets, etc.).

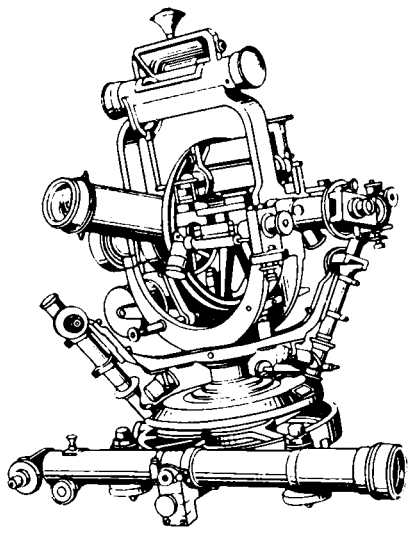
TRAJECTORY. See ORBIT.

TRAJECTORY CORRECTION. A manoeuvre performed in accordance with the results of trajectory measurements and flight forecasts in order to correct the trajectory of a spacecraft. When correcting the flight trajectory, a correction pulse is imparted to the spacecraft by an engine, the direction of the pulse depending on the results of trajectory measurements. The consumption of power, as well as the accuracy and direction of the correction pulse depend on the point of the trajectory at which the correction manoeuvre is performed. From the point of view of power consumption, it is more advantageous to correct the trajectory of spacecraft making a long-distance flight (to the Moon, Mars, Venus) at an early stage of the flight; on the other hand, a lower accuracy of the correction pulse is required at approach to the target. A compromise solution satisfying both of the above contradictory requirements is to be adopted at selection of the point of trajectory correction. The inevitable error of trajectory correction and the gradually increasing deviation of the actual trajectory from the predicted one makes it necessary to repeat the correction manoeuvre several (2—3 and more) times in the course of a long-distance flight.

TRAJECTORY MEASUREMENTS. Determination of the parameters of the trajectory (orbit) of a spacecraft. The results of trajectory measurements serve for computing the further motion of the spacecraft and obtaining control data required, as an example, for performing TRAJECTORY CORRECTION. In most cases trajectory measurements are made by means of ground radio stations (see RADIO NAVIGATION).

TRANSIT (ASTRONOMICAL). An astronomical instrument consisting of a TELESCOPE that can rotate only in the plane of a CELESTIAL MERIDIAN, its axis being directed horizontally and pivoted on special bearings. It is used to determine the moment of passage of stars, the Sun, the Moon, or planets through the meridian, and their zenith distances at this moment.

TRANSIT (ENGINEERING). A portable instrument with a sight tube turning about its vertical and horizontal axes, and two precision graduated circles intended for reading off the angles in the horizontal



Engineering transit.

(azimuths) and vertical (altitudes) planes. The advantage of this instrument over a theodolite is its higher accuracy in taking measurements, particularly in the vertical plane. It is used for determining geographical coordinates of some point, time correction, etc.

TRANSIT OF PLANETS. See CULMINATION.

TRANSPIRATION COOLING. The most effective, and therefore prospective, means of hydrodynamic heat protection of the wall surfaces of rocket engine components. It is effected by feeding a coolant through a porous, permeable, or perforated wall into the boundary-layer flow of hot gases. Wide application of transpiration cooling is deterred by a number of difficulties in design and production.

TRANSPIRATION MOISTURE. Liquid liberated by higher plants into the atmosphere of the space farm. In higher plants the main organs of transpiration are leaves. The amount of transpiration moisture depends on the anatomical structure and biochemical peculiarities of various plant species, and on environmental factors. In plants of the same species the amount of transpiration moisture is proportional to the total surface area of the leaves, and increases in optimal temperature conditions, greater soil humidity or intensification of illumination. By cultivation of vegetables, a daily yield of 1.5 to 10 l of transpiration moisture per 1 m^2 of sown area can be obtained. Transpiration moisture is sufficiently pure in chemical composition, though it may have a slight odour. The total content of organic admixtures is less than 10 mg/l. However, transpiration moisture contains volatile substances, emitted by structural and covering materials of the space farm. In extended space flights transpiration moisture is one of the main sources for replenishing the water supply, it can be used for hygienic purposes. After filtering through charcoal it can be used for drinking and cooking. The amount of water consumed by a plant in the accumulation of 1 g of dry substance, known as the transpiration coefficient, is expressed in g.

TRANSPORTER ERECTOR. A mobile carriage-mounted ERECTOR.

TRANSPORTER-ERECTOR TROLLEY. A wheeled trailer carriage used for hauling space vehicles over motor roads or railways from the maintenance area to the launch pad and for installing the space vehicle on the launcher.

The trolley consists of a chassis, frame, cradles, supports and grips, a remote-control mechanism for opening the grips so as to release the space vehicle after it has been installed on the launcher, a grip for fixing the trolley on a stationary erector or devices for fastening the rope system of a mobile erector. Some transporter-erector trolleys are equipped with a mechanism for lowering the space vehicle onto the launcher and for its lateral displacement in order to improve the accuracy of installation.

TRANSPORT FASTENING of launch vehicle. A set of supports, cradles, braces, grips, clamps, etc., mounted on road and railway carriages, erectors, in railway cars, on barges, and dollies carrying launch vehicles into the freight compartment of aircraft. The number of supports depends upon the launch vehicle design, the layout of its supporting frames, and the distribution of maximum loads. It is advisable to use two supports—front and rear—one of which (usually the front support) serves for accepting the radial

loads, the other (the rear one) being used for accepting the axial and radial loads of the launch vehicle in transit. The rear support is to provide for the launch vehicle to turn about its transverse axis.

Two supports are also most suitable for erecting the launch vehicle on the launcher, provided a missile-handling dolly or erector arm is used for this operation. In this case, the bending deformations of the transporter frame or erector arm are practically not transmitted to the shell of the launch vehicle. However, additional calibrated supports provided with counter-weights or spring devices are to be placed in between in order to lessen the deflection in cases when the front and rear supports are too far apart. During transportation of the launch vehicle with the space body, this support is sometimes placed under the space body and quite frequently it acts as the front support during erection. Side supports are often used for ensuring an adequate resistance of the launch vehicle to side loads. Transport (and overload) girders are sometimes fixed to the ends of the launch vehicle stages for relieving them of overloads and fastening the stage during transportation. These girders are removed prior to assembling the launch vehicle.

TRANSPORT GRAB. A device for fixing a launch vehicle on the supports and cradles of transport facilities and erector arms. Collet-type remote-controlled grabs operated electrically or manually are commonly used. After erecting the launch vehicle, the grabs of the front support are drawn apart and the erector arm (or trolley) is lowered. The rear support attachment of the launch vehicle prevents its radial or axial displacement and allows it to turn about the transverse axis in case of deformation of the erector arm or the transporter.

TRIAXIAL ORIENTATION of spacecraft. See SINGLE-AXIS ORIENTATION.

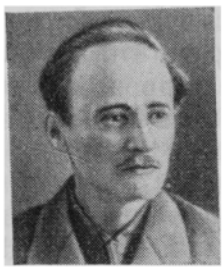
TRIPROPELLANT. A propellant for liquid-propellant engines, consisting of 3 components separately delivered into the combustion chamber. Tripropellants can produce the maximum SPECIFIC IMPULSE. Thus, a propellant consisting of fluorine, hydrogen and lithium or of oxygen, hydrogen and beryllium, according to calculations, is capable of producing a specific impulse close to the maximum potential one for chemical rocket propellants, ~500 s. There is a great difficulty in overcoming the loss due to the very high content of the condensed phase in the combustion products of these propellants.

The oxygen-hydrogen-beryllium propellant can be used in the form of a bipropellant if beryllium is preliminarily dispersed in liquid hydrogen, forming a suspension or colloidal solution. This propellant was developed in GDL (1930). A propellant was proposed in GDL, in which a usual two-component propellant is supplemented by a 3rd heavy component (mercury, organic compounds of mercury, etc.). In spite of the decrease in the specific impulse, the effectiveness of the propellant is substantiously increased for the 1st stage of the rocket. The high toxicity of the heavy components, however, prevents their use.

TROPOSPHERE. The lower region of terrestrial atmosphere from the sea level up to an altitude of 8 km in the polar regions and up to 18 km in the equatorial regions, containing over 80% of the total mass of the air. Atmospheric refraction, absorption and dispersion of radio waves, as well as

fluctuations of the intensity and phase of radio waves, ATMOSPHERIC NOISE and other physical phenomena occur in the troposphere.

TSANDER, Fridrikh Arturovich (1887—1933). Soviet scientist and inventor in rocket engineering. When still a student, he studied the works of K. E. TSIOLKOVSKY and took an interest in problems of space flight. On graduating from the Riga Polytechnical Institute he went to work at rubber factories (from 1914 to 1918). In 1919 started working at the Motor aircraft factory in Moscow. In 1921 at an inventors' conference he delivered a report on the project of an interplanetary aircraft; in 1924, in the magazine *Tekhnika i zhizn* he published an article entitled *Perelyoty na drugie planety* (*Flights to Other Planets*) in which he set forth his principal idea, that of a combination of a rocket and an airplane for take-off from Earth, and subsequent burning of the metallic components of the airplane in the combustion chamber of the rocket engine to increase the rocket's flight range. In 1930—31, Tsander built and tested with compressed air and gasoline his first jet engine, the *OP-1*. The first liquid-propellant engine designed by Tsander, the *OP-2* (LOX and gasoline), was tested in 1933. Tsander took part in designing the ENGINE 10 and the rocket *GIRD-X*. From 1931, he took part in the work of the MOSCOW GROUP FOR STUDY OF REACTIVE MOTION, and after collaboration in setting up the GROUP FOR STUDY OF REACTIVE MOTION in 1932 remained to work in this group.



Tsander's book *Problema polyota pri pomoshchi reactivnykh apparatov* (*The Problem of Flight by Means of Reaction Vehicles*) (1932) is devoted to theoretical investigation of various problems of design and flight of space rockets, the search for optimum thermodynamic cycles of air-breathing and rocket engines, and problems of combustion of certain metals and their alloys in oxygen and fluorine. His other thermodynamic calculations of rocket engines and works on other problems of rocket engineering were published posthumously.

Tsander extensively popularized the idea of space flight by lecturing throughout the Soviet Union. A crater on the reverse side of the Moon bears Tsander's name.

TSIOLKOVSKY, Konstantin Eduardovich (1857—1935). Soviet scientist, founder of modern cosmonautics and rocket technology. He was born to a forester's family in the village of Izhevskoye, Ryazan Province. Deafness (a complication after scarlet fever) prevented him from entering school. In 1879, he passed teacher's examinations without having attended lectures. Beginning with 1880, taught mathematics at a school in the town of Borovsk, and beginning 1898, mathematics and physics at a school for girls in the town of Kaluga. In 1885 started working on the theory and design of an all-metal airship and later on the design of a metal-frame monoplane (the calculations were described and published in 1894). The outstanding engineering ideas

embodied in these works could not be realized due to the lack of material resources. In 1897, Tsiolkovsky built Russia's first wind tunnel and, with the assistance of the Academy of Sciences, tested the simplest models in it (1900).

Tsiolkovsky's most valuable contributions were made in the theory of reactive motion, where his talent and creative ingenuity were revealed to the full. His works anticipated the development of science in this field by many decades and they were fully appreciated only many years after publication. As far back as 1883, Tsiolkovsky suggested using the principle of reactive motion for creating interplanetary vehicles. His work *Issledovanie mirovykh prostranstv reaktivnymi priborami* (*Exploration of Cosmic Space by Reaction Apparatuses*, English title *Rockets into Cosmic Space*), appeared in 1903. In this work Tsiolkovsky for the first time deduced the laws of the motion of a rocket as a body of a variable mass in space without gravity and in a gravity field, demonstrated the possibility of using rockets for interplanetary travel, determined rocket efficiency, investigated the effect of air drag on rocket motion and many other things. This work of Tsiolkovsky charted the most rational ways of developing space engineering. These problems were also the subject of works by Tsiolkovsky in 1911—12, 1914 and 1926. His work *Kosmicheskie raketnye poyezda* (*Space Rocket Trains*), in which he investigated the theory of a special type of multi-stage rockets, was published in 1929.

Tsiolkovsky found a number of important engineering solutions for rocket design. For the first time in the world he evolved the fundamental principles of the theory of liquid-propellant engines and specified the elements of their design. He considered and recommended various propellants for rocket engines. Numerous technical ideas expressed by Tsiolkovsky have been incorporated in the designs of modern rocket engines and space vehicles.

Considerable space in Tsiolkovsky's works is devoted to problems of organization of interplanetary travel and its prospects. He argued that leading from the first artificial Earth satellites, interplanetary stations and flights to the planets is a direct road to the establishment of cities and great communities in interplanetary space and to the adaptation of outer space to the needs of expanding humanity.

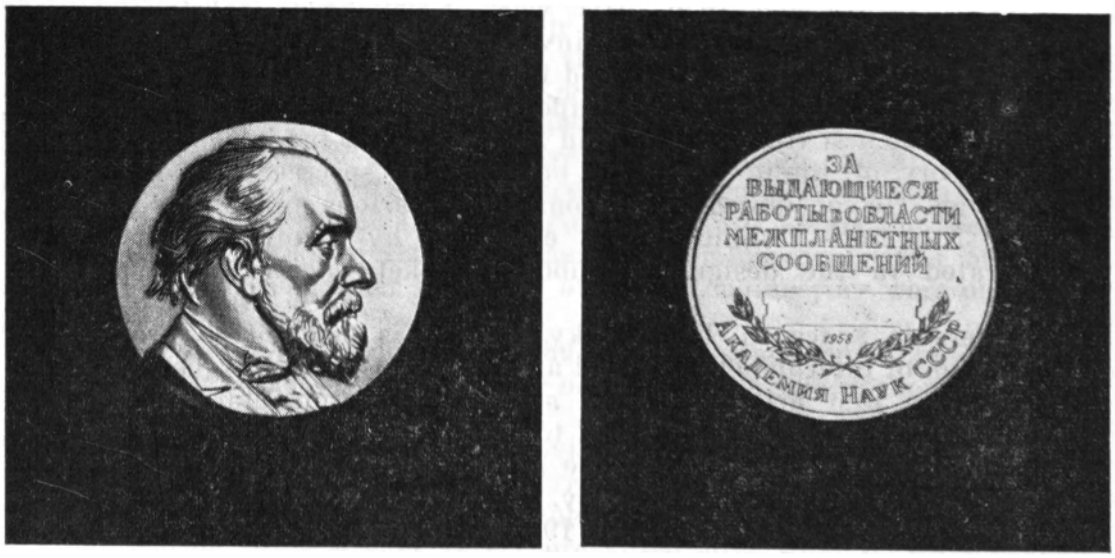
After the October Revolution of 1917, Tsiolkovsky's scientific activities received full support from the Soviet state. In 1918 Tsiolkovsky was elected Member of the Socialist Academy. In 1919 he was elected Honorary Member of the Society of Amateur Cosmologists; in 1921 the Council of People's Commissars of the Russian Federation appointed him a personal life pension. In 1924, Tsiolkovsky was made Honorary Professor of the Zhukovsky Air Force Academy. The subsequent development of aviation and space flight, the great victories of Soviet science and technology in the conquest of outer

space, revealed with particular clarity the genuis of Tsiolkovsky, the Russian scientist whose creative daring became the basis of space exploration and opened before man the expanses of the Universe. Tsiolkovsky's works have been published in *Collected Works* (in Russian, v. 1—4, 1951—1964).

TSIOLKOVSKY FORMULA. The basic formula describing the motion of a rocket and determining its characteristic velocity. Was published in 1903. According to the Tsiolkovsky formula, the characteristic velocity is equal to the absolute value of the product of the engine exhaust velocity by the logarithm of the ratio of the rocket take-off mass M_0 to its final mass M_f that remains after the burnout of the propellant mass M_p:

$$v = u \ln \frac{M_0}{M_f} = u \ln \left(1 + \frac{M_p}{M_f}\right).$$

The Tsiolkovsky formula applies also to multi-stage rockets, in which case the characteristic velocities of individual stages are summed up. This fundamental formula shows that the velocity acquired by the rocket is directly proportional to the exhaust velocity, i.e. to the specific impulse, which is the principal characteristic of a rocket engine, while the effect of the relative propellant load and design of the rocket is logarithmic. Therefore the capacity of a rocket depends mainly on the specific impulse of its engine. It also follows from this formula that in order to achieve a pre-determined flight velocity, the correct determination of the relative weight of the rocket structure is of paramount importance.



Tsiolkovsky medal.

TSIOLKOVSKY MEDAL. A gold desk medal awarded by the USSR Academy of Sciences for outstanding contributions to space science and exploration. The first three medals were awarded in 1958 to commemorate the world's

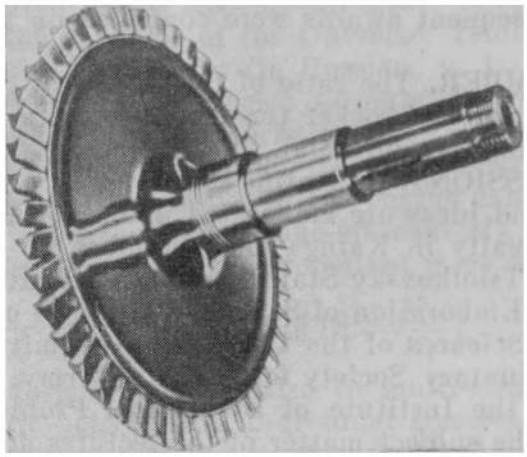
first orbital flights. They were presented to the chief designer of the rocket, the chief designer of the rocket engine, and the chief designer of the rocket control system. Subsequent awards were conferred on the 16 Soviet cosmonauts (1961—69).

TSIOLKOVSKY NUMBER. The ratio of the weight of the usable propellant to the final weight of the rocket (or its stage) after propellant burnout (M_p/M_f in the Tsiolkovsky formula).

TSIOLKOVSKY SESSIONS. Scientific sessions at which Tsiolkovsky's scientific heritage and ideas are elaborated upon. Since 1966 these sessions have been held annually in Kaluga on September 17—19. They are sponsored by the K. E. Tsiolkovsky State Museum of History of Cosmonautics, the Commission for Elaboration of Scientific Heritage of K. E. Tsiolkovsky at the Academy of Sciences of the USSR, the Committee on Cosmonautics of the DOSAAF (Voluntary Society for Assisting Army, Air Force and Navy of the USSR), and the Institute of Biomedical Problems of the Ministry of Public Health. The subject matter of the lectures delivered includes life and activities of Tsiolkovsky, his scientific creative work, problems of rocket and space engineering, mechanics of space flight, problems of space biology and medicine, aviation and aeronautics, and history of aeronautics and cosmonautics. The Tsiolkovsky sessions are attended by both prominent researchers and young scientists from Moscow, Kaluga and numerous other cities of the USSR. Along with plenary and sectional sittings, the programmes of the Tsiolkovsky sessions envisage visits to places associated with Tsiolkovsky's life and work and excursions to the Museum of History of Cosmonautics. Participants of the sessions give lectures for the residents of Kaluga. Proceedings of the Tsiolkovsky sessions are issued as a special publication.

TUKHACHEVSKY, Mikhail Nikolayevich (1893—1937). Soviet military leader, Marshal of the Soviet Union. In 1931, Deputy People's Commissar for Army and Navy Affairs and Vice-Chairman of the USSR Revolutionary War Council. Encouraged the development of rocketry in the USSR. Supervised the GAS DYNAMICS LABORATORY. Regularly assisted and supported the activities of the GDL, the GIRD and the LenGIRD. Organized the ROCKET RESEARCH INSTITUTE in Moscow.

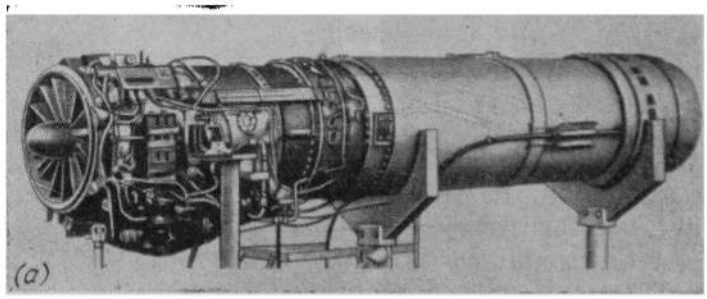
TURBINE. A machine (motor) with blades for transforming the potential energy of a gas (gas turbine) or liquid (hydraulic turbine) into mechanical energy. Gas turbines are used in propellant-feed systems to drive the main and BOOST PUMPS, while hydraulic turbines drive the boost pumps only. To transform the energy of the fluid, the turbine has a stator with nozzle or fixed blades and a rotor with rotating blades. A turbine can be impulse or reaction type, axial or radial, single- or multi-stage. Uncooled gas turbines are usually used in turbopump units (see IMPULSE TURBINE, REACTION TURBINE). See Fig., p. 472.

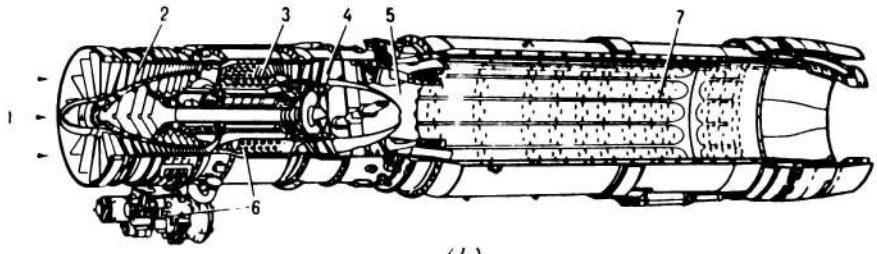


Turbine rotor of turbopump unit of *Gamma* liquid-propellant engine (Great Britain).

TURBOJET ENGINE. The main type of modern aircraft air-breathing jet engine. It comprises a compressor, a combustion chamber, a gas turbine and a jet nozzle, as well as fuel-feed, starting and other systems. Supersonic turbojet engines may find application in the 1st stages of AEROSPACE PLANES.

TURBOPAUSE. The level in the UPPER ATMOSPHERE at an altitude





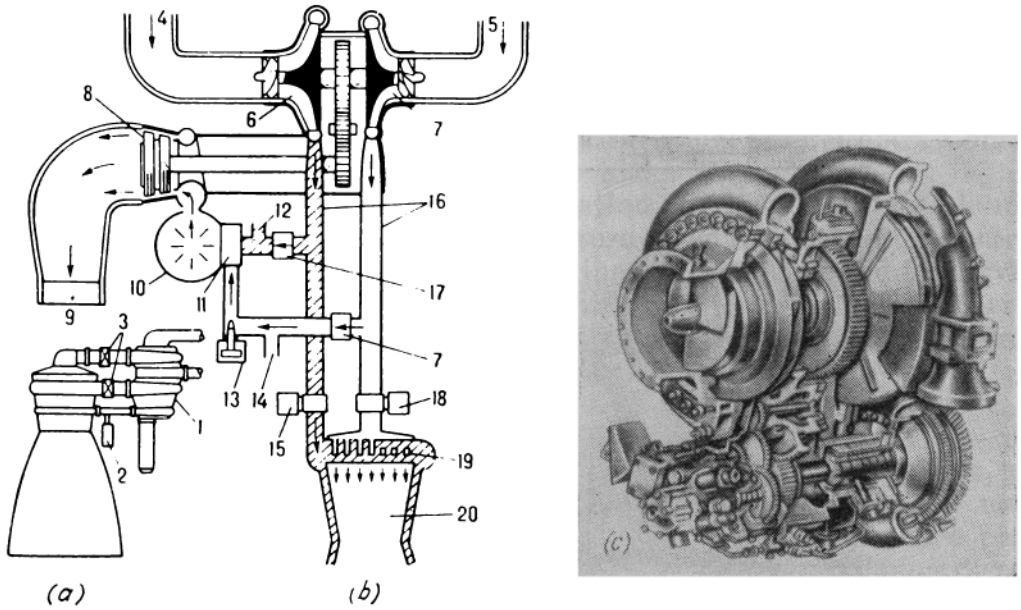
(b)

Turbojet engine: (*a*) outside view; (*b*) section.

1—air inlet; *2*—air compressor; *3*—combustion chamber; *4*—turbine for driving the compressor; *5*—jet nozzle; *6*—controls and auxiliary units; *7*—afterburner chamber.

of about 105—115 km, above which turbulent mixing of atmospheric constituents is negligible.

TURBOPUMP UNIT. A unit consisting of one or several pumps and the gas turbine driving them and intended for feeding liquid propellant components or the working fluid to the rocket engine. The working fluid for the turbine



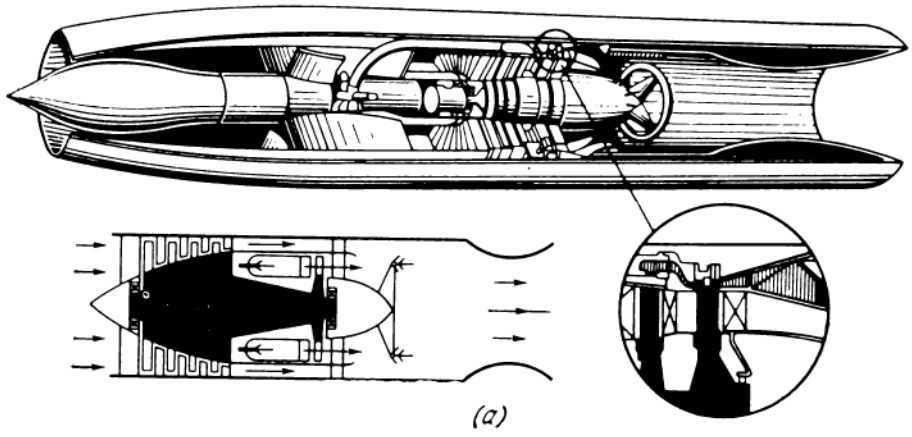
Turbopump unit: (*a*) diagram of a turbopump unit powered by gases withdrawn from the combustion chamber of a liquid-propellant engine (USA); (*b*) diagram and section of the turbopump unit of the British *RZ-2* liquid-propellant engine producing thrust of 62,145 kg (turbine power, 4,120 h.p.; propellant flow rate, 255 kg/s; outlet pressure, 50 atm; weight, 265 kg); (*c*) structure of turbopump unit of the *RZ-2* engine.

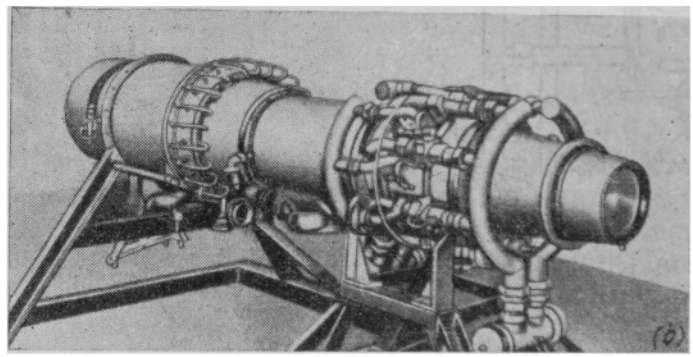
1—turbopump unit; *2*—powder cartridge for starting; *3*—fuel and oxidizer supply valves; *4*—fuel (kerosene) supply from tank; *5*—oxidizer (liquid oxygen) supply from tank; *6*—fuel supply pump; *7*—oxidizer supply tank; *8*—pump-driving turbine; *9*—outlet of exhaust gases from turbine; *10*—gas generator; *11*—propellant inlet valve of gas generator; *12*—fuel supply from starting tank; *13*—oxidizer supply adjuster; *14*—oxidizer supply from starting tank; *15*—main valve of fuel supply into rocket engine; *16*—propellant pipelines; *17*—non-return valves (prohibiting the supply of starting propellant into rocket combustion chamber); *18*—main valve of oxidizer supply; *19*—injector of rocket engine; *20*—combustion chamber.

of the turbopump unit is usually supplied from GAS GENERATORS or STEAM-GAS GENERATORS. Methods of bleeding gas from the engine combustion chamber are being developed. Heating (evaporation) products of the thrust chamber COOLANT are sometimes used as the turbine working fluid.

TURBOROCKET ENGINE. A combination engine; an integration of a TURBOJET ENGINE with a liquid-propellant one. The expediency of using turborocket engines on AEROSPACE PLANES is under consideration.

TURPENTINE, $C_{10}H_{16}$. A rocket fuel. A colourless or yellowish odourous high-boiling liquid; density, 0.85—0.87 g/cm^3; m.p., below —55°C; b.p., 155—180°C; a mixture of terpines. Is oxidized and becomes resinous in the air; stable in the absence of atmosphere; only slightly corrosive. Tur-





Turborocket engine: (*a*) the engine diagram and design layout; shown enlarged in the circle is the combustion chamber of the liquid-propellant rocket engine and the gas turbine that drives the compressor; (*b*) outside view (experimental engine, USA).

pentine is somewhat more effective than KEROSENE. Proposed as a fuel for rocket engines by K. E. Tsiolkovsky in 1914; since 1933 it was used in GDL as fuel in hypergolic propellants with nitric acid and nitric acid oxidizers. Is used in France (in combination with nitric acid).

TWO-DIMENSIONAL FLOW. A flow whose parameters depend on two independent variables, e.g., Cartesian coordinates. Plane and AXISYMMETRIC FLOWS are instances of two-dimensional flows.

UCHINOURA. Japanese missile range on Kyushu Island near the town of Uchinoura, Kagoshima. The construction of the range, begun in the spring of 1962, has not been completed yet. Uchinoura will occupy 50 km². A launch complex for launch vehicles of the *Lambda* series has already been built. Several firings of this rocket have been made and preparations are under way to orbit the first Japanese Earth satellite by means of this rocket. Construction has been completed of a launch complex for launch vehicles of the *Mu* series. The construction costs of this complex are estimated at about $3,000,000. In the next few years it is planned to orbit a series of Japanese Earth satellites from Uchinoura. Another Japanese missile range Mikisawa in the Akita prefecture is used for launching probes. Construction of a rocket range at Tanagashima is under way.

UMBILICAL TOWER. A stationary installation of a launch site or a launcher in the form of a tower-like metal structure used for bringing electrical, propellant-loading, drain, and pneumatic lines to the rocket and for servicing the latter. The umbilical towers are assembled on or near the launcher and are provided with break-away unions for connecting the rocket with ground supply lines. The towers are equipped with lifts and swing-down platforms. They can be over 100 m high with a base of up to 20 m square.

UNDISTURBED MOTION. The motion of a celestial body along one of the so-called Keplerian orbits which are conic sections (hyperbola, ellipse, parabola, circle, straight line). Undisturbed motion results when the motion of a celestial body is regarded as due solely to the attraction of a central body, the effects of all other bodies of the system, drag, etc. being disregarded. Thus, undisturbed motion corresponds to the PROBLEM OF TWO BODIES. The study of undisturbed motion is the first stage in any investigation of the true motion of a celestial body. For example, in studies of planetary motion, the motion of the planet is first examined as due solely to the attraction of the Sun, neglecting the effects of the other planets and bodies of the solar system; thus, the resulting motion is undisturbed. Investigation of the effects of other planets in subsequent stages consists in determining DISTURBANCES.

UNICELLULAR ALGAE. Green algae consisting of single microscopic cells, of which CHLORELLA is representative. Unicellular algae have a high reproduction coefficient, their cultivation in very dense suspensions and harvest of the continuously growing BIOMASS are possible. The cultivation process can be intensified to any degree required. This permits to design compact, lightweight installations with low energy consumption. As members of a spaceship biocomplex, unicellular algae may be employed for BIOLOGICAL AIR REGENERATION, production of food and feed biomass and utilization of a certain part of liquid and solid biological waste (see FOOD RECYCLING).

UNIVERSAL LAW OF GRAVITATION. The law of gravitational properties of matter discovered by the great English scientist Newton. It holds that every particle of matter attracts every other particle with a force proportional to the product of their masses and to the inverse square of their distance.

UNIVERSE. The surrounding world infinite in time and space and composed of endlessly changing forms of matter and energy in constant motion. (See SOLAR SYSTEM, GALAXY, METAGALAXY).

Upper atmosphere

UPPER ATMOSPHERE. The part of the Earth's atmosphere, extending from a height of ~20—30 km up to its outer boundary. At altitudes of 20—30 km intensive photochemical interactions begin in the atmosphere; somewhat higher, ionization processes are added. All these processes predominate in the upper atmosphere as compared to the lower atmosphere. Molecules, atoms, ions and electrons, moving together with the Earth in interplanetary space, form its atmosphere whose density decreases substantially with height. Because of frequent collisions, particles of the upper atmosphere up to 500—1000 km move randomly; higher up their movement (ascent and return) is practically collisionless. The closer to the vertical is the direction of a particle and the larger its velocity, the higher altitude it reaches.

The atmospheric region above ~500 km is called the exosphere. Neutral particles of the atmosphere move in the exosphere along ballistic trajectories and in closed orbits, while charged particles travel only along geomagnetic lines of force. All neutral particles of interplanetary space can freely penetrate through the Earth's atmosphere up to the bottom of the exosphere. The geomagnetic field prevents, however, outer charged particles from entering the exosphere. These particles penetrate through the Earth's atmosphere the deeper, the higher their velocities and the closer the direction of their motion coincides with that of the polar geomagnetic lines of force. Thus, the outer atmosphere boundary is not the same for proper and outer particles. The external atmospheric layers and interplanetary medium consist mainly of ionized particles. The interplanetary ionized gas has its own magnetic fields. Flowing around the geomagnetic field, this gas breaks down the latter at a distance of several Earth's radii depending on the geomagnetic activity (usually about 8—10 Earth's radii). The near space, where stable geomagnetic lines of force exist, is sometimes called the magnetosphere.

Importance of the upper atmosphere. It has long been found that ionization of the upper atmosphere defines the conditions of long-range propagation of radio waves. Though air density at high altitudes is negligible as compared to its near-ground values, the upper atmosphere decelerates satellites appreciably and defines their lifetime. Radio communication on the Earth and in space depends substantially on the state of ionization; active neutral and ionized particles can complicate the operation of spacecraft equipment. Charged particles of the greatest energy can penetrate through rather thick walls and constitute a radiation hazard, especially to live organisms during space flights. The exploration of the upper atmosphere offers great possibilities for the solution of a wide scope of scientific problems related to its origin and interaction with the surrounding medium.

Methods of exploring the upper atmosphere. The upper atmosphere is being extensively explored at present with the aid of instruments on board rockets and satellites. Valuable information concerning the upper atmosphere and processes taking place in it is given by ground-based observations: propagation of radio and sound waves, luminous phenomena (e.g., auroral), variations of the geomagnetic field, etc. Of highest value is simultaneous combined exploration by ground-based and space-borne instruments.

Basic processes in the upper atmosphere. The upper atmosphere absorbs mainly solar electromagnetic radiation with wave-lengths shorter than

3000 Å; it causes dissociation of air molecules to atoms. Radiation with wave-lengths shorter than 1200 Å produces ionization of molecules and atoms. In the polar regions, charged particles of high energy also enter sporadically, increasing dissociation and ionization. The energy, introduced by electromagnetic radiation and charged particles, produces heating of the upper atmosphere. Heating is also enhanced by magnetohydrodynamic waves generated, as geomagnetic disturbances take place, at the magnetosphere's boundary and absorbed in the region with the highest ion density. Heating of the upper atmosphere is followed by its expansion upward; non-uniform heating produces circulation intensified by solar and lunar tides. Besides, circulation and oscillatory movements of the lower atmosphere are also partly conveyed upwards.

The energy introduced into the upper atmosphere is only partially transformed into heat producing expansion of the atmosphere. The other part of it transforms into potential energy of excited molecules, free atoms, ions and electrons. The temperature in each atmospheric region is defined by the balance between the thermal fluxes entering and leaving it. These are very complicated processes not yet fully understood. The temperature is non-uniform both horizontally and vertically. The velocity distribution of molecules, atoms, ions and electrons in their highest density region differs from the equilibrium (Maxwellian) distribution substantially. Excessive velocities are especially characteristic of newly formed particles (atoms and electrons formed as a result of dissociation and ionization, respectively). The mean temperatures of neutral particles, ions and electrons sometimes differ considerably; it may be especially high for electrons (thousands of degrees higher). At 20—100 km the atmosphere is cooled primarily through IR radiation of, mainly, ozone and hydroxyl, but also of water vapour and carbon dioxide. Above 80 km cooling is effected through hydroxyl IR radiation, diffuse emission of nitrogen oxide in the visible region, emission of atomic oxygen at wave lengths near 63 μ, 6300 and 5577 Å, and through thermal conductivity causing heat to flow from the warmer higher regions downwards, to ~80 km. During aurorae, emission increases sharply and many different emissive lines appear in the visible and UV spectral regions. Electrons entering with energy of some tens of keV produce X-rays as well.

The energy released on recombination of atoms into molecules and ions and electrons into neutral particles is transformed partly into light emission and partly into heat. These processes occur much later than the primary processes of dissociation and ionization do, therefore the heating of the atmosphere somewhat lags behind the primary processes. The situation is further complicated by circulation in the vertical and, especially, the horizontal directions; the transformation of kinetic energy to heat is also delayed. As a result of the circulation, newly formed atoms, ions and electrons are carried away from the regions where they were formed; for this reason the heat outflow can not only lag behind absorption of the active agents, but may even influence other regions, including more extensive ones. Cooling of the atmosphere, after the daytime heating, continues at night.

The problem of the heat balance is inseparable from that of DISSIPATION of the Earth's atmosphere and its ACCRETION of extraterrestrial matter, phe-

nomena as yet slightly investigated. Dissipation produces a cooling effect; the light atoms of hydrogen and helium escape from the atmosphere most readily. The escape of ions and electrons is encumbered by the geomagnetic field, where these particles can move only along lines of force. Their escape from and penetration into the atmosphere are possible only in the polar regions. There are grounds to believe that proton fluxes, entering the upper atmosphere in high latitudes during aurorae, may reach 10^{10} $cm^{-2} \cdot s^{-1}$. In spite of the fact that near-ground layers contain a lot of hydrogen in water vapour, its relative concentration above 100 km is many orders less. This indicates that hydrogen dissipation predominates over accretion.

The upper atmosphere absorbs a great deal of micrometeoric matter (about 10^4 t per day over the whole Earth's surface). As a result it accumulates a considerable amount of readily ionized metallic atoms. Sometimes the penetration of micrometeoric dust into cold regions at an altitude of about 80 km results in the appearance of so-called noctilucent clouds observed at twilight; these clouds originate on freezing of micrometeoric dust.

The circulation of the upper atmosphere (ionized and therefore electrically conductive) in the geomagnetic field is accompanied by generation of electromotive forces. Wind speeds up to several hundreds of m/s produce electromotive forces reaching 10^{-4} V/cm. It results in the formation of electrical current systems and, consequently, magnetic fields. Of highest regularity are the current systems produced by circulation due to tides; these currents are located mainly in the region which has the highest conductivity, i.e. near 100 km. Electrical fields in the upper atmosphere cause directed drift of ions and thus substantially re-distribute ionization. A considerable effect is produced in the case of longlived metallic ions. Sometimes these ions concentrate into very thin sporadic layers at 90—130 km. Since the highly electrically conducting regions extend predominantly along geomagnetic lines of force, the electrical fields from the lower layers are transferred upward into the magnetosphere and substantially influence the movement of charged particles there. Wind motions practically cease above 200—300 km, where the geomagnetic lines of force begin to retain charged particles. At local region boundaries additional electric fields are produced because the electron velocities are considerably higher than the velocities of heavy ions. At these boundaries slight electrical fields arise, preventing electrons from escaping. Diffusion of ionization centers in the presence of the above-mentioned fields is called ambipolar diffusion.

Atoms and ions are extremely active chemically. They readily react with neutral particles; in the upper atmosphere chemical activity is intensified owing to the presence of especially active vibratory-excited molecules. As a result, a chain of complicated chemical transformations takes place there, followed by electromagnetic emission. The presence of intermediate products is sometimes easily detected through their twilight fluorescence. Thus, sodium, calcium, lithium and ortho-helium atoms and ionized nitrogen molecules have been detected. In the upper atmosphere molecules and ions of nitrogen oxide, as well as negative ions are produced, especially at night when the intensity of the destroying light is low. The most effective process is molecular oxygen dissociation; oxygen atoms readily attach them-

selves to oxygen molecules, forming triatomic ozone molecules. The highest ozone density is observed at 30 km. Ozone actively absorbs the solar UV radiation with wave-lengths shorter than 3000 Å; besides, the ozone layer partly absorbs the Earth's IR radiation; that is why at about 50 km there exists a temperature maximum.

The ionic and electron densities in the upper atmosphere depend not only on the rate of ion formation, but on the lifetime of the ions and electrons prior to their recombination into neutral particles. Electrons recombine very slowly with atomic ions and very rapidly with molecular ones. Ions of atomic oxygen and nitrogen readily react with oxygen and nitrogen molecules, forming molecular ions. For this reason, in the presence of a large quantity of neutral molecules, ions and electrons recombine very fast. Though the qualitative picture of the recombination process is well understood, its quantitative treatment is rather difficult so far because of the great variability in efficiencies of relevant reactions. The rates of these processes increase when molecules are vibratory-excited; high-speed electrons excite the states of vibration of nitrogen molecules. It was found recently that as a result of this the electron density decreases when the electron temperature increases. The stability of metallic ions is attributable to the fact that they do not readily react with neutral molecules of the atmosphere and do not take part in producing molecular ions that are easily recombined.

Characteristics of the upper atmosphere regions. Because of the intensive circulation of the upper atmosphere, its relative atomic composition remains constant up to 100—150 km, but the relative molecular structure does not remain invariable even below these altitudes.

In the 20—80-km region there is much ozone, above 100 km the dissociation of molecular oxygen, and above 200 km, that of molecular nitrogen begins. Above 150—200 km the atmospheric circulation is insufficient for steady and uniform intermixing, so above these levels lighter particles begin to predominate. At 150—180 km atomic oxygen predominates, further up light helium and especially hydrogen atoms do. The precise composition of the upper atmosphere varies substantially, depending on the time of day, season of the year, the latitude, and the degree of solar activity and geomagnetic disturbances.

The temperature of the neutral particles also depends on the composition of the upper atmosphere. In the upper atmosphere two temperature minima are observed, of about 200° and 180°K at ~15 and ~80 km, respectively. At ~50 km there exists a temperature maximum of about 270°K. At higher altitude the temperature increases usually up to ~1000°—1500°K at 200—400 km and higher up it remains practically constant. At higher altitudes temperature fluctuations are more substantial. In the daytime in low and middle latitudes the temperature of the upper atmosphere has its maximum value in the illuminated region; at night, however, its temperature in the polar regions is higher, especially during aurorae and geomagnetic disturbances. The density of the upper atmosphere also varies considerably as a function of the same factors (see Table, p. 480).

Within several Earth's radii the density of neutral particles falls down to values less than 10^{-24} g/cm^3. Above 150 km the higher the altitude, the

Altitude, km	0	100	200	300	400	600	800
Density, g/cm^3	$1.3 \cdot 10^{-3}$	$5 \cdot 10^{-10}$	$3 \cdot 10^{-13}$	$2 \cdot 10^{-14}$	$3 \cdot 10^{-15}$	10^{-16}	10^{-17}

greater the density variations; below 150 km they are less significant and of the reverse direction. The density of the upper atmosphere above 150—200 km substantially increases with growth of solar activity and geomagnetic disturbances; it also varies to a small extent in the 27-day period of the Sun rotation. The density of the upper atmosphere above 150—200 km is considerably higher in the daytime than at night; there are also noticeable annual variations. The density variations in the upper atmosphere are caused, in the main, by the variations in solar radiation at wave-lengths shorter than 1200 Å. The density of the upper atmosphere at high altitudes, however, sharply increases at the time of aurorae and geomagnetic disturbances. It is due to the heating of the upper atmosphere by magnetohydrodynamic waves and incoming high-speed charged particles.

For describing the pressure in the upper atmosphere it is most convenient to use the concept of "height of homogenous atmosphere" (see also SCALE HEIGHT), which means the height of the atmosphere column of uniform density equal to the real atmosphere density at a given level; when the weight of this column is equal to the weight of the real atmosphere column above this level, the pressure is equal to the product of the density by the height of the homogeneous atmosphere at a given level. The height of the homogeneous atmosphere increases from the value of 10 km at ~100 km up to 60 km at ~300 km and to still greater values at higher altitudes. The upper atmosphere region with considerable ionization, which governs wave propagation, is usually called the ionosphere. The ionosphere below 100 km is called the *D*-region; ionization there is produced generally by solar X-rays and exists practically in the daytime only. In high latitudes it is additionally produced by high-speed electrons and protons. Under usual daylight conditions the electron density reaches 10^4 cm^{-3}; at night it decreases considerably, but when high-speed electrons and protons penetrate it, rises higher than 10^4 cm^{-3}. Molecular ions predominate in this region, including such complicated ions as H_3O^+ and $H_5O_2^+$; the lifetime of the ions is less than 100 s. In the *D*-region, where electrons collide very frequently with surrounding atmospheric particles, radio waves are intensively absorbed.

The ionosphere at 100—150 km is called the *E*-region; under normal daytime conditions its electron density reaches $2 \cdot 10^5$ cm^{-3}, but at night the density falls to about 10^4 cm^{-3}. During aurorae, at any time of the day, ionization grows sharply and becomes extremely non-uniform. During the daytime and at the time of aurorae molecular ions predominate in this region. Diurnal ionization is produced partly by solar radiation at wavelengths shorter than 1200 Å and partly by X-rays of the ionosphere itself. Under normal night conditions, however, metallic atomic ions are an important constituent. The mean lifetime of molecular ions is less than 1000 s.

Plate V

Upper atmosphere

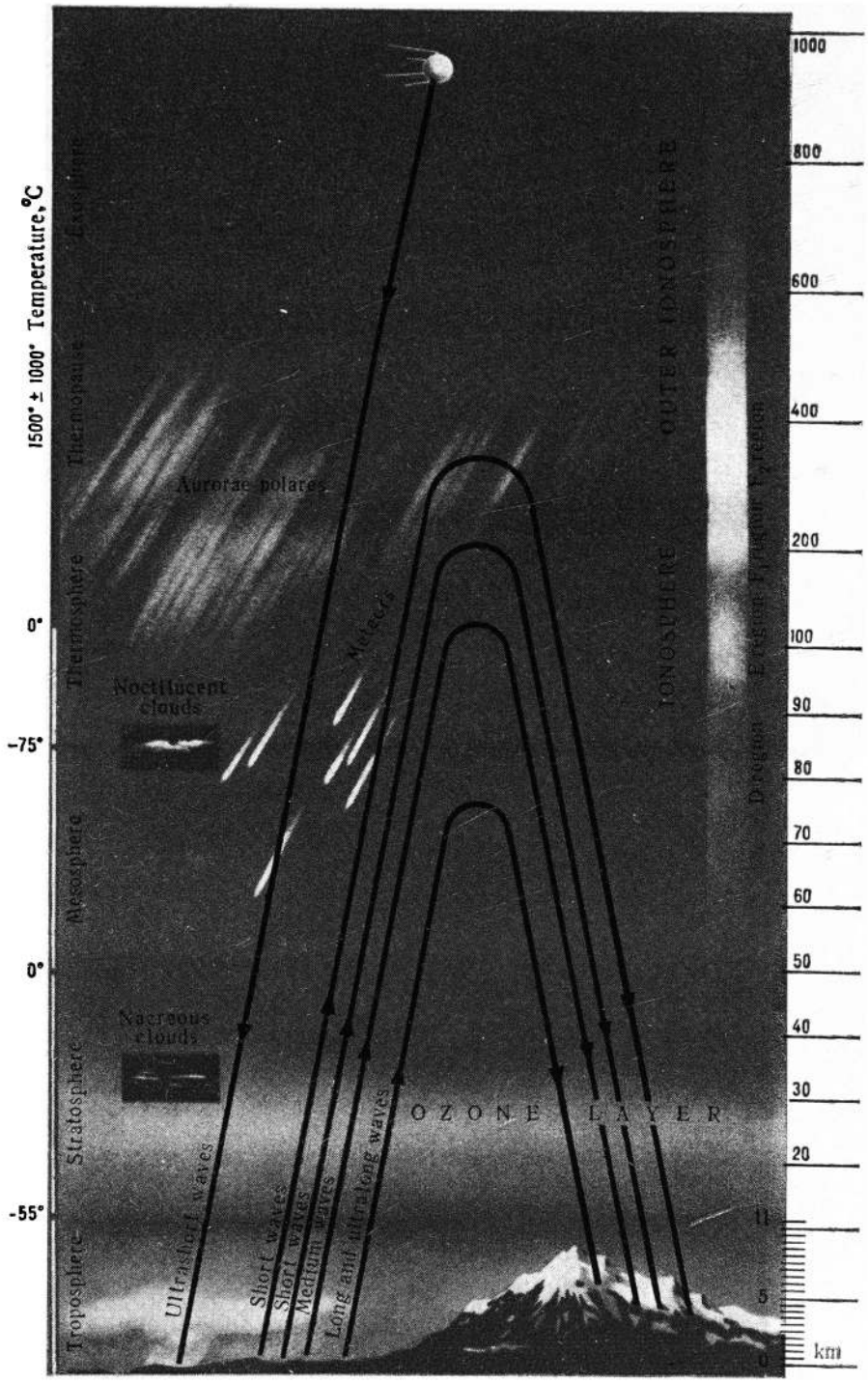
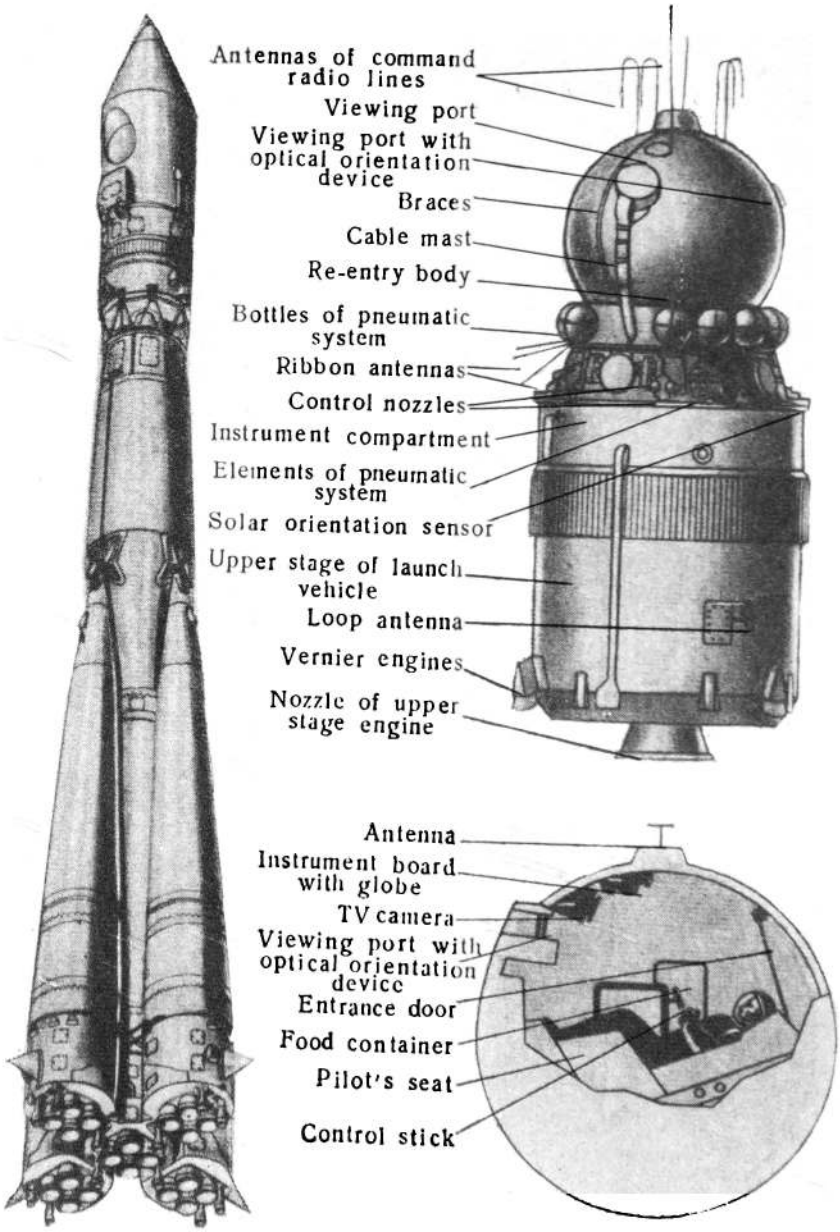


Plate VI

Vostok



1. *Vostok* space vehicle. 2. *Vostok* spacecraft. 3. Re-entry capsule

As indicated above, atomic ions of metals live considerably longer; sometimes they concentrate into narrow sporadic layers (E_s). The ionospheric region above 150 km is occupied by the F_2 and F_1 layers originating through absorbtion of solar radiation with wave-lengths shorter than 500 A. The F_2 layer (ionization maximum) is located at ~300 km; under normal daytime conditions the electron density there reaches $2 \cdot 10^6$ cm^{-3}, but at night it is one order less. The density of long-lived ions of atomic oxygen increases with height; their mean lifetime can reach a day and more. Nocturnal ionization is chiefly a residue of the diurnal one. Some additional ionization is produced by the inflow of outside ions and electrons from the illuminated regions, which occurs owing to the circulation of the upper atmosphere. During geomagnetic disturbances and aurorae the electron density of the F_2 layer in middle and, especially, high latitudes decreases, and in low latitudes somewhat increases. This phenomenon is explained by variations in the electron temperature and, in the first place, of the molecule density, caused by intensification of the circulation of the upper atmosphere at that time. During the daytime a small additional ionization maximum sometimes appears, located below the F_2 layer at 150—200 km and called the F_1 layer Its characteristics are intermediate between those of the E and F regions. The F_2 and F_1 layers reflect electromagnetic waves of the radio broadcasting range, which accounts for their long-distance propagation.

The non-uniform structure of ionization of the upper atmosphere influences absorption and scattering of radio waves. The size of a usual discontinuity exceeds tens of km. From the lower boundary of the exosphere the atmospheric region begins where collisions of particles are practically of no importance. In this region particle motion is governed by the geomagnetic field and charged particles display three types of motion: a rotational motion around the geomagnetic lines of force, an oscillatory one along them, and a rotational-drifting one around the Earth. The higher the energy of the particles and the distance from the Earth, the faster they drift around the Earth. As a charged particle oscillates, the angle between its velocity and the geomagnetic line of force increases as it enters a stronger geomagnetic field or decreases when it enters a weaker one. At the so-called mirror points this angle becomes equal to 90°, and the charged particles reverse their motion (i.e. are reflected). Such motion of charged particles in the magnetosphere is violated by their rare collisions with atmospheric particles near the mirror points, by discontinuities and variations in the geomagnetic field and by electric fields coming into the magnetosphere from the ionosphere and interplanetary space. Small electric fields can substantially influence the motion of low-energy charged particles; at appropriate electric field configurations, radial drift becomes possible both inwards and outwards.

The magnetosphere is filled with various particles of rather a wide energy range. The density of thermal protons and electrons decreases from 10^4—10^5 cm^{-3} at the lower boundary of the exosphere; their density at the magnetosphere boundary has not yet been established definitely, different sources giving values from one to several hundreds per 1 cm^3. The energy of such protons and electrons, called thermal plasma, increases to some extent from

the boundary of the exosphere up to the outer boundary of the magnetosphere; the distribution of the thermal plasma round the Earth is non-uniform.

The magnetosphere also contains protons and electrons of higher energy; every kind of particles has its peculiar distribution in space at different distances from the Earth, their intensity being somewhat higher in the equatorial plane. Such particles drift steadily around the Earth for rather a long time and form a radiation belt. Protons of an energy of 10—100 MeV and electrons with energies higher than 40 keV produce an intensity maximum at a distance of 1.5 Earth's radii from its center; their fluxes in the equatorial plane are estimated approximately by 10^5 and 10^9 cm^{-2}/s^{-1}, respectively. At 2—5 Earth's radii, protons with an energy of several hundreds of keV concentrate; their flux in the equatorial plane reaches 10^9 cm^{-2}/s^{-1}. The density of electrons with an energy above 40 keV at a distance of 4—5 Earth's radii is very unstable; in the equatorial plane, typical fluxes are of the order of 10^7—10^9 cm^{-2}/s^{-1}. All the above-mentioned particles in the radiation belt drift around the Earth in the course of several hours.

During geomagnetic disturbances and aurorae rather dense electron fluxes with energies of several keV and, partly, several tens of keV along with protons of energies equal to several hundreds of eV and several keV penetrate through the magnetosphere and enter the lower layers of the upper atmosphere. Sometimes they penetrate separately and the regions of penetration have a discrete structure. Especially dense fluxes are observed in the case of electrons with an energy of several keV; during such penetration, strong fluctuations of the geomagnetic field and of the additional current systems in the ionosphere are observed. The latter particles differ from particles of the usual radiation belt. The energy yielded by the upper atmosphere during aurorae and geomagnetic disturbances exceeds that of the usual radiation belt. Particles of the inner radiation belt may partially be products of disintegration of neutrons, produced in the lower atmosphere by cosmic rays. However, the precise physical picture of the origination of particles of the radiation belts and aurorae, as well as variations in their distribution and intensity, has not yet been established. It is most probable that they enter the magnetosphere and the ionosphere from interplanetary space.

It is known that the Sun constantly ejects streams of high-temperature ionized gas, forming the SOLAR WIND. Solar wind speeds from several hundreds to thousands of km/s, at a mean density of several charged particles per 1 cm^3, have been observed. But at present there are contradictory experimental data. On approaching the Earth at a distance of 12—14 Earth's radii the solar wind produces a shock wave in which the energy is redistributed among different kinds of particles; then the particles flow around the geomagnetic field, forming a plasma tail on the antisolar side. The flowing around the geomagnetic field is followed by the deformation of the field, especially at its outer parts. Particles of the radiation belts and of the solar wind reaching the ionosphere change their energy under these conditions to greater or lesser values.

The study of penetration of charged particles from outer space into the ionosphere and the magnetosphere is hindered mainly by the fact that while

geomagnetic disturbances and aurorae occur only occasionally, the solar wind is a rather permanent phenomenon. One can only assume the existence of some reasons for such a discrepancy: sporadic appearance in the solar wind of specific structures of the magnetic fields; variations in the relative composition of hydrogen and helium ions (recently high-energy helium ions were detected in the radiation belts); formation of electric field systems in the ionosphere, facilitating penetration of incoming charged particles, and variations in the density and energy of the solar wind particles.

URANUS. The seventh planet in the order of distances to the Sun. The mean distance to the Sun is 19.182 AU which is 2,870,000,000 km, the orbital eccentricity 0.0472, the inclination of orbital plane to ecliptic 0° 46.4′. The mean orbital velocity is 6.8 km/s, the sidereal revolution period 84.015 years. The dia of Uranus is 47,100 km, or 3.70 (Earth=1); compression, 1 : 18; mass, 14.52 (Earth=1) or $8.68 \cdot 10^{28}$ g; its mean density is 1.58 g/cm^3; gravitational acceleration of gravity, 0.99 (Earth=1) which is equal to 9.72 m/s^2. The second cosmic (parabolic) velocity on the planet is 21.6 km/s. The period of rotation is 10.8 h, the inclination of the equator to the orbital plane is 98°. The main atmospheric constituents are methane and hydrogen; the amount of methane is estimated as a layer 1.5 km thick at standard temperature and pressure, that of hydrogen, 18 km. Uranus has 5 satellites.

V

VACUUM INSULATION. See THERMAL INSULATION OF CONTAINERS.

VACUUM-POWDER INSULATION. See THERMAL INSULATION OF CONTAINERS.

VACUUM TESTS. Tests conducted with a view to checking the effect of high vacuum on spacecraft and their separate systems (temperature control system, attitude control system, retro-rocket, etc.). The test object is tested for leakage in a vacuum chamber with a pre-selected vacuum level. Gaseous helium is used as a leak-detecting medium, since it is capable of penetrating into the minutest pores. Among the leakage-testing methods is the *outgassing method* in which gas leakage from the tested equipment is estimated by measuring the pressure increase in a vacuum chamber with an initial vacuum of 10^{-4}—10^{-6} mm Hg. This method, though simple, is unreliable, since leaks may develop not only in the tested equipment, but in the chamber, too. The *method of measured leaks* consists in filling the vacuum chamber with a known amount of gaseous helium in order to calibrate the helium leak detector; then the tested object is filled with helium and placed into the chamber in which a vacuum of 10^{-4}—10^{-6} mm Hg is set up. Then the leak detector determines the helium concentration which exceeds the permissible level if the equipment is not vacuum-tight. The *gas blowing method* consists in pumping air out of the tested equipment and blowing helium over the seams and joints; the concentration of helium that penetrates into the object through voids is recorded by a leak detector, and a critical concentration starts a sound signal. In the *pressurization method*, helium is pumped into the object and the joints are examined with a test gun communicating with the leak detector; this method makes it possible both to check whether the equipment is leaking and to pinpoint the location of leakage, if any.

VALIER, Max (1895—1930). German designer of rockets and advocate of space flight. Entered Innsbruck University in 1913 where he studied astronomy, physics, and mathematics. Served as pilot in the Austrian Air Force from 1917 to 1918. Assumed and continued his studies in the Vienna, Innsbruck and Munich Universities in 1918—22. Studied the possibilities of jet propulsion as applied to ground vehicles (automobiles, railroad trolleys, boats, etc.) and aircraft. Valier and F. Sander, a specialist in pyrotechnic rockets, with the financial support of the manufacturer F. von Oppel, built a race car propelled by powder booster and sustainer rockets, that was tested in March 1928. He developed and tested a racing car equipped with 24 solid-propellant rockets in 1929. In 1930 he began experiments with liquid-propellant engines and was killed during one of these tests by an explosion of the combustion chamber. Author of the *Raketenfahrt. Vorstoss in dem Weltraum. Eine technische Möglichkeit* (*Rocket travel. Breakthrough into the Space. A Technical Possibility*).

VAN GU (about 1500). The legendary Chinese inventor of a manned powder-propelled rocket vehicle. Van Gu linked up two box kites with a frame

provided with a seat and installed 47 bottom-mounted powder rockets ignited simultaneously on command by 47 men. Died in an explosion during an experiment. A crater on the far side of the Moon has been named in his honour.

VEGETATION PERIOD. Period of activity, growth and development of plants. The duration of the vegetation period can be changed by controlling the environment in space greenhouses.

VEHICLE ASSEMBLY BUILDING (VAB). This main building of the MAINTENANCE AREA of a space centre is equipped with a variety of assembly and check-out equipment providing for de-inhibiting of the launch vehicle elements after shipment, assembly and check-out of the vehicle stages, vertical or horizontal assembly of the vehicles, their check-out, and mating of space bodies. Sometimes a separate building is constructed with a complex of assembly and check-out equipment for post-shipment de-inhibiting, assembly and check-out of the space bodies.

In the case of horizontal assembly the launch vehicles are transferred by bridge cranes onto a transporter-erector; vertical assembly of the launch vehicle is performed on the launcher platform. The dimensions of the VAB depend on the dimensions of the launch vehicles assembled and on the type of assembly; for vertical assembly the height of the building reaches 160 m; the VABs used for super-giant launch vehicles are the largest buildings in Europe and the USA. When assembling launch vehicles with solid-propellant boosters, the vertical assembly building is used for assembling the central part of the launch vehicle comprised of liquid-propellant engine stages, while the solid-propellant boosters are mated with the central part in a special building. In this case separate sections of the solid-propellant stages are pre-assembled in the solid-propellant booster assembly building. The VAB is provided with laboratory equipment for checking control instruments, ground sources of electric power, pneumatic equipment for testing the vehicle stage tanks, electric and pneumatic lines, lifting cranes of up to 300-ton capacity, assembly jigs, mating trolleys, trestles, supports, service mechanisms, ladders and other miscellaneous equipment. For super-giant launch vehicles the VAB is equipped for assembly and welding of vehicle tanks from pre-fabricated sections delivered from respective manufacturers and for hydraulic and other tests of these tanks. Some VABs are large enough to hold up to 4 heavy launch vehicles being assembled and checked out. The distance between the VAB and the launch pad is selected so as to ensure safety for the building in the event of a vehicle explosion on the pad or during lift-off.

VENTILATION. Forced circulation of air in a spaceship cabin effected by fans. It is necessary since during a space flight there is no air convection inside the cabin because of weightlessness. Consequently, there is no heat emission from the human body, and zones of heat stagnation appear. During long periods spent by man in the cabin, the rate of air flow should be within 0.2 to 0.3 m/s, with a relative air humidity of 30 to 70% and temperature 20° $\pm$3°C. The ventilation of the space inside the space suit must ensure evacuation of carbon dioxide and moisture excreted by the spaceman. In cases of sharp fluctuation of environmental temperature, humidity content

of 5 to 8 g/m³ or physical activity of the spaceman, the air exchange rate inside the space suit should be not less than 250 l/min, and temperature of gaseous mixture fed into the suit, +10° to +22°C.

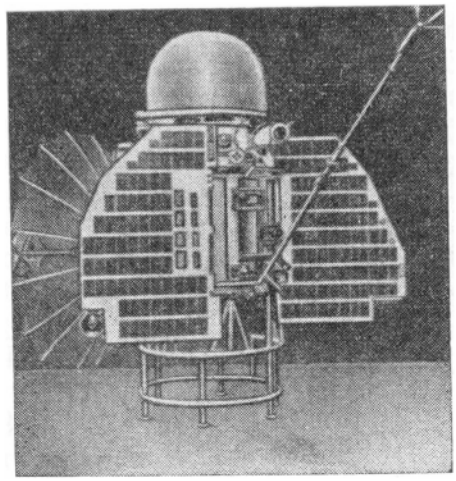
VENUS. A planet of the solar system, second in distance from the Sun. Its mean distance from the Sun is 0.723 AU (108.2 million km), eccentricity is 0.0068, inclination of orbit to the ecliptic plane is 3° 23.7′, mean orbital velocity is 35 km/s. Venus makes one full revolution around the Sun in 224.7 days. The diameter of Venus (together with cloud envelope) equals 12,228 km or 0.960 (Earth=1); mass equals $4.87 \cdot 10^{27}$ g or 0.815 (Earth=1); mean density is 5 g/cm³; acceleration of gravity on the equator is 869 cm/s² or 0.89 (Earth=1); second cosmic velocity is 10.2 km/s. The smallest distance between Venus and the Earth is 38 million km and the greatest 261 million km. The following estimates have been given of the period of rotation of Venus: 1; 1.5; 4; 15; 24; 224.7; and 243 Earth days. Different observers give varying estimates of the inclination of the equator to the orbit of the planet as 0°, 14°, 32°, and 39°. This great divergence in results is due to the fact that the surface of Venus is covered with a dense layer of clouds and is practically unobservable. The atmosphere of Venus was first discovered by M. V. Lomonosov in 1761 during an observation of the planet's transit across the solar disc. Since the atmosphere is very opaque only its outmost layers can be studied.

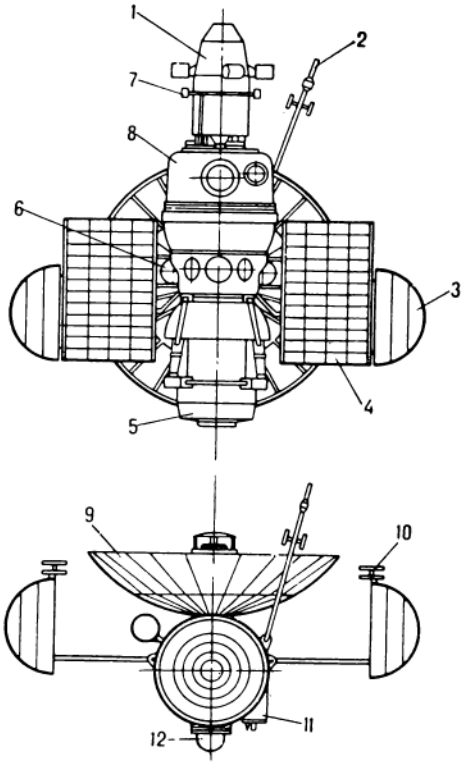
According to the data provided by the *Venyera-4*, *Venyera-5* and *Venyera-6* automatic interplanetary stations, temperatures in the range of 400°-530°C and atmospheric pressures of 60—140 at can be expected on the surface of the planet. Similar values have been obtained by Earth-based radio-astronomical and radar measurements. The results obtained by the American *Mariner-5* station were 480°C and 100 at. In the circumpolar regions the temperature is about 150° lower than at the anti-solar point. IR measurements from the Earth indicate that the temperature in the cloud layer is 235°—240°K. According to measurements made by *Venyera-5* and *Venyera-6*, carbon dioxide constitutes 93—97% of the planet's atmosphere, other components are nitrogen and inert gases (2—5%) and oxygen ($\gtrsim$ 0.4%); water vapour content at altitudes corresponding to the pressure of 0.6 at is 4 to 11 mg/l. The surface of Venus has a dielectric constant of 3—4, which corresponds to dry sandy on rocky soil. No magnetic field or radiation belt has been discovered in the vicinity of Venus by space exploration. A hydrogen corona was found to exist. *Venyera-1*, the first Soviet automatic interplanetary station sent towards Venus in February, 1961, flew by at approximately 100,000 km; the American automatic interplanetary station *Mariner-2* flew by Venus at a distance of 35,000 km in December 1962, and sent back to Earth scientific information; *Venyera-3* was the first to hit the planet on March 1, 1966; on October 18, 1967, *Venyera-4* entered venusian atmosphere and analyzed its composition, temperature, density, and pressure, descending to a level at which the pressure was 18 at; on October 19, 1967, *Mariner-5* flew by the planet at a distance of 3970 km and sent measurements back to the Earth; the Soviet automatic interplanetary stations *Venyera-5* and *Venyera-6* made a gradual descent through the atmosphere of Venus on May 16 and 17, 1969 to a level at which the pressure was 27 at.

VENYERA. Name of Soviet automatic interplanetary stations launched in the direction of Venus beginning with 1961. Besides scientific experiments, these stations carry an intricate set of equipment including an attitude control system, vernier rocket engines, long-range radio communication and orbital measurement equipment, solar batteries for energy supply, etc.

Venyera-1 was launched on February 12, 1961. The station weighed 643.5 kg. On May 19 and 20, 1961, it passed Venus at a distance of about 100,000 km and went into circumsolar orbit with a perihelion of 106 million km and an aphelion of 151 million km.

Venyera-2 was launched on November 12, 1965. Its mission was to fly by Venus at a close distance. The station weighed 963 kg, and carried a TV system and scientific instruments for space research. On February 27, 1966, *Venyera-2* passed Venus at a distance of 24,000 km and went into circumsolar orbit with a perihelion of about 107 million km and an aphelion of about 179 million km.





Top: Automatic interplanetary station *Venyera-1*.

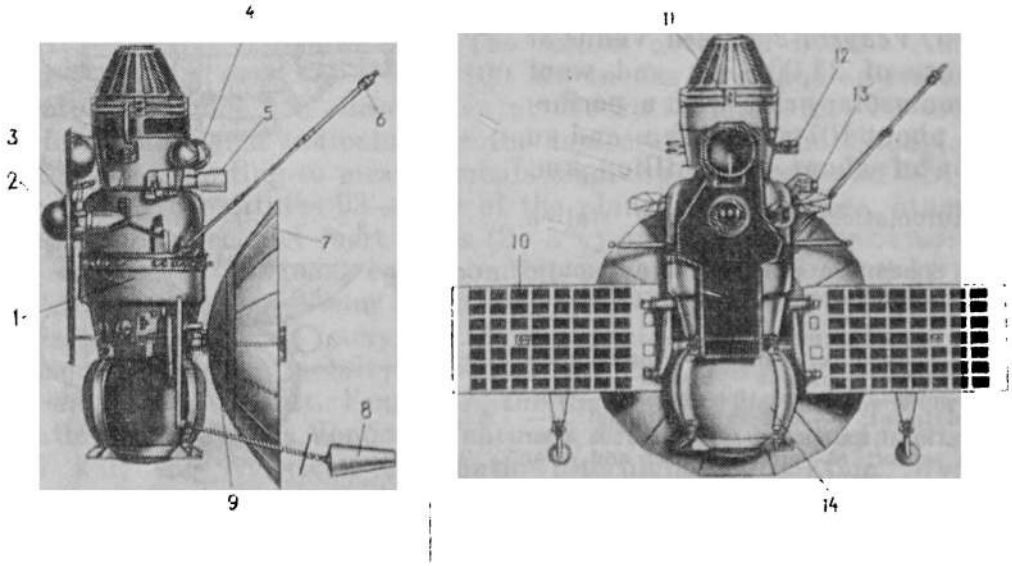
Bottom: Schematic diagram of automatic interplanetary station *Venyera-2*.

1—trajectory-correction engine unit; *2*—magnetometer probe; *3*—temperature-control system radiators; *4*—solar cell panels; *5*—special compartment; *6*—orientation system bottles; *7*—micro-engines of orientation system; *8*—orbital compartment; *9*—high-gain antenna; *10*—semi-directional antenna; *11*—continuous solar radiation sensor; *12*—precise stellar and solar orientation sensor.

Venyera-3 was launched on November 16, 1965, with a landing mission on Venus. The station weighed 960 kg and had a parachute-borne spherical entry body 900 mm in dia with a heat-protection coating. The entry body contained a radio communication system, scientific instruments, electric power sources, and medallions bearing the Coat of Arms of the USSR. During the flight, 63 radio communication cycles were held and the trajectory was corrected. The station reached the planet on March 1, 1966, and was the world's first automatic spacecraft to reach another planet.

The pennant landed on Venus, March 1, 1966, by the automatic interplanetary station *Venyera-3*. The sphere contains a medalion bearing a replica of the Coat of Arms of the USSR on one side and a representation of the planets of the solar system on the other.

Venyera-4 was launched on June 12, 1967. Scientific information was transmitted during 114 radio communication cycles during the flight. When the station was 12,000,000 km from the Earth, its trajectory was corrected to assure arrival at the planet. On October 18, 1967, after travelling ~350,000,000 km, the station entered venusian atmosphere at second cosmic velocity and released an entry body carrying 2 radio transmitters operating in the dm waveband, telemetry equipment, scientific instruments, radio altimetre, temperature control and energy supply systems. The entry body had a dia of 1 m. After aerodynamic deceleration the body's velocity was



General view of *Venyera-4* automatic interplanetary station.

1—orbital compartment; *2*—star sensor; *3*—Sun sensor of continuous solar orientation; *4*—gas bottles; *5*—sensor of Sun—Earth orientation; *6*—transducer and rod of magnetometer; *7*—high-gain parabolic antenna; *8*—low-gain antenna; *9*—radiation panels of temperature control system; *10*—panel of solar batteries; *11*—vernier engine; *12*—micro-rocket engine of astro-orientation system; *13*—cosmic particles counter; *14*—entry body.

reduced from 10,700 m/s to 300 m/s; then the parachute system was deployed; the instruments operated continuously throughout the 1.5 h descent on the night side of the planet and measured the pressure, density, temperature and chemical composition of the venusian atmosphere. The station weighed 1106 kg, the entry body, 383 kg. The entry body delivered to the surface of Venus another medallion bearing the Coat of Arms of the USSR. This was the first time an automatic interplanetary station launched from the Earth made a gradual descent in the atmosphere of another planet. Direct measurement data on properties of the atmosphere of Venus in the pressure range of 0.5—18 at have been received; it has been established that the planet has no radiation belt and practically no magnetic field.

Vertical alignment

Venyera-5 and *Venyera-6* were launched on January 5 and 10, 1969, respectively. Each of these spacecraft weighed 1130 kg. The two automatic interplanetary stations incorporated entry bodies of stronger design, each weighing 405 kg and housing an enlarged set of scientific and measuring instruments to continue the investigation of interplanetary medium and venusian atmosphere commenced by *Venyera-4*. On board the stations were medallions bearing the Coat of Arms of the USSR and bas-reliefs of V. I. Lenin. Radio communication cycles were held regularly at frequency 929.746 Mc/s (*Venyera-5*, 73 cycles, and *Venyera-6*, 63). After making preplanned trajectory correction at a distance of 15.5—15.7 million km from the Earth, the stations reached Venus on May 16 and 17, 1969, respectively. The entry bodies carrying scientific experiment were automatically separated from the stations to make an aerodynamic descent which reduced their velocities from 11.17 km/s to 210 m/s; the parachute systems were then operated and the entry bodies made a gradual descent in the atmosphere on the nocturnal side of the planet, the duration of the parachuting was 51—53 min. The joint flight of the two interplanetary stations has provided a large quantity of information including data on atmospheric properties in the pressure range of 0.5—27 at, which is greater than the range covered during the *Venyera-4* flight.

VERNAL EQUINOX. The point on the CELESTIAL SPHERE where the CELESTIAL EQUATOR and the ECLIPTIC intersect and at which the Sun in its apparent annual path crosses the equator and passes from the Southern Hemisphere into the Northern Hemisphere (about March 21).

VERNE, Jules (1828—1905). French writer, author of science fiction novels. Described space flights in such books as *De la Terre à la Lune* (*From the Earth to the Moon*, 1865), *Autour de la Lune* (*Around the Moon*, 1870), *Hector Servadac* (1877), and *Les cinq cent millions de la begum* (*The Five Hundred Millions of the Begum*, 1879). A crater on the far side of the Moon has been named in his honour.

VERNIER ENGINE. A low-thrust rocket engine serving to control the rocket's flight according to a predetermined programme. Two or more vernier engines are usually installed. The lateral moment is created by deflecting or differentiating the thrust of the engines which remain fixed.

VERTICAL ALIGNMENT. Setting the launchh veicle erected on the launcher in a strictly vertical position. The launch vehicle or individual elements of the space-borne flight control system must be vertical within a few minutes

of arc. Vertical alignment is attained by setting the reference support plane of the launch vehicle on a prealigned fixed base plane of the launcher or by turning the launcher base plane and the launch vehicle about two mutually perpendicular axes by means of special lifting mechanisms of the launcher. Automatic systems of vertical alignment have been developed.

VERTICAL CIRCLE. Any great circle on the CELESTIAL SPHERE whieh passes through the zenith.

VERTICAL GYROSCOPE. A gyro system carried by a satellite and made up of a single or several gyros. It records any angular deviation of one of the satellite's axes from the local planet vertical. The angular attitude of the gyros is corrected (continuously or periodically) according to signals supplied by the VERTICAL-LINE PLOTTER. The use of gyros reduces the random alternating error of the vertical-line plotter and permits intermittent supply of power to the latter, this being necessary for power economy, etc.

VERTICAL-LINE PLOTTER. A satellite-borne instrument for determining the direction to the centre of the orbited planet. The operation of the vertical-line plotter may be based on various physical principles: radar tracking of the planet surface, optical methods, shielding of cosmic radiation by the body of the planet, sensing of the direction of lines of force of the gravitational field of the planet, etc. The most widely used type of vertical-line plotters is the INFRARED REFERENCE VERTICAL.

VERTICAL SPACE PROBE. A scientific space station launched by the USSR on October 12, 1967, by means of the last stage of a launch vehicle to an altitude of 4400 km to study the upper layers of atmosphere and the ionosphere of the Earth and circumterrestrial space by vertical sounding. The main object was to obtain data on vertical distribution of the properties of the ionosphere (concentration of electrons and positive ions and temperature of electrons); total intensity of cosmic rays and radiation doses behind various radiation barriers in flight through the radiation belt; and the density of neutral hydrogen. Highly accurate in-flight orientation of the vertical space probe was provided. To eliminate any distortions in measurements due to gases emanated into the environment from the structure and from the rocket engine, special materials were used in the design of the station, while the launch vehicle, after sending the probe into the pre-selected trajectory, was diverted by its power plant. In addition to scientific equipment, the probe accommodated radio telemetry and trajectory measurement systems.

VESTIBULAR STIMULANTS. Environmental effects causing vestibular responses, e.g., changes in motion velocity or in magnitude and direction of the gravity force. They are known as "adequate vestibular stimulants" whose perception is conditioned by the structure and functions of the vestibular analyzer. Vestibular responses may also be caused by thermal and electric stimulation of the labyrinth and the vestibular nerve (caloric and galvanic tests); these are known as "non-adequate stimulants". Dosed vestibular stimulants are used to evaluate the sensitivity and reactivity of the vestibular analyzer (see VESTIBULOMETRY).

VESTIBULAR TRAINING. A complex of measures to increase the organism's resistance to the effects of VESTIBULAR STIMULANTS. Vestibular training includes physical exercises (active training), which must comprise motions causing

stimulation of the vestibular receptor (bending, turning, jumping, exercises on gymnastic paraphernalia), as well as repeated exposure of the organism to angular and linear acceleration created by rotating installations, four-bar swing, etc. (passive training). A special part of vestibular training involves the use of flying vehicles. Vestibular training develops the ability to balance, and spatial orientation. It also suppresses undesirable vestibulo-vegetative responses.

VESTIBULOMETRY. A complex of methods and procedures for examination of vestibular functions. Vestibulometry is the evaluation of the responses to stimulation of the vestibular analyzer (see VESTIBULAR STIMULANTS). In clinical practice qualitative analysis of vestibular responses (their presence and character) is used most often. However, in the last few decades methods for their quantitative evaluation have also been developed. For this purpose use is made of stimulation by angular accelerations created by electrically rotated installations, and electric stimulation of the labyrinth. These are methods that permit precise dosing of the magnitude and the duration of the action of vestibular stimulants. The sensitivity threshold and reactivity of the vestibular analyzer to stimuli of progressing force thus applied can be determined by instrument records of vestibular responses that can be quantitatively analyzed. Ordinarily, these responses are the illusion of counter-rotation and vestibulo-somatic reflexes (oculogyric reactions and muscular tone re-distribution). Dynamic vestibulometry is used to determine changes in the functional state of the vestibular analyzer caused by pathological processes or various environmental factors. Vestibulometry is also used for evaluating the efficiency of VESTIBULAR TRAINING.

VETCHINKIN, Vladimir Petrovich (1888—1950). Soviet specialist in aerodynamics. Graduated from the Moscow Higher Technical School in 1915. Lectured at that school, the Air Force Engineering Academy and the Moscow Aviation Institute (professor from 1928). In 1918 joined the Central Aero-Hydrodynamics Institute. Studied problems relating to rocket flight dynamics. A crater on the far side of the Moon has been named in his honour.

VIBRATION (1). *Spacecraft.* Oscillations of separate structural elements of a spacecraft or of its carrier vehicle. The main cause of vibration is the operating engine. Vibration of separate elements may also appear due to pulsation of propellant components in pipelines or other reasons. The frequency of vibration ranges from a few c/s to several kc/s. It is commonly characterized by frequency and acceleration.

(2). *Rocket engine.* Mechanical oscillations of a rocket engine which are always present during its operation. Vibrations are caused by combustion and other causes. Developed vibrations may cause the rocket engine's destruction (see SELF-EXCITED VIBRATION and FORCED VIBRATION). One of the most formidable tasks in designing rocket engines is the preclusion of vibration of impermissible intensity.

(3). *Living organism in flight.* Complex oscillatory motions with frequent changes in direction and parameters, and characterized by frequency, amplitude and so-called vibro-acceleration, i.e., speed change per unit of time, m/s^2 or g (see ACCELERATION). The effect of vibration on the human organism is a specific sensation of commotion (pallesthesia). Vibration is termed general

Vibration excitation

when it affects the entire organism, and local when it influences separate parts of the organism. General vibration takes place in the POWERED-FLIGHT PHASE of the flight trajectory, when the oscillations caused by the operating rocket engines are passed on from the spaceship to the crew, as well as on the return trajectory, when the spaceship entering the dense atmosphere is exposed to the action of aerodynamic forces. Man can tolerate the vibrations experienced in space flight; vibro-accelerations are usually within 0.1 g and only in rare cases reach 1 g. The unpleasant sensations caused by vibrations may be diminished by using vibration-absorbing devices. When selecting spacemen, their individual reactions to vibration is taken into account.

VIBRATION EXCITATION in rocket engine. The operation modes of a rocket engine which give rise to SELF-EXCITED VIBRATION. There are rigid and soft rates of vibration excitation. Starting of the rigid-rate self-excited vibration of a system is by an initial impulse of sufficient force, e.g., a shock wave directed into the rocket engine's combustion chamber. Soft-rate vibration begins from initial impulses no matter how small, e.g., as a result of fluctuations in the self-excited vibratory system proper. Thus, the soft rate is observed during the experimental definition of the rocket engine's stability boundary by gradually changing its work duty.

VICTIMS OF SPACE FLIGHT. The conquest of sea and air took a heavy toll of lives. The reason for that was lack of knowledge of the new environment and its effects upon a human being, as well as insufficient development of the means used. To conquer outer space, man had to overcome great difficulties. History knows many rocketry investigators who lost their lives while designing or operating rockets. Among them are VAN GU, the hero of Chinese legends, the German designers M. VALIER (explosion of a liquid-propellant engine in 1930) and Tilling (explosion of a powder rocket in 1931), Soviet test pilots G. Y. Bakhchivandzhi (aboard the rocket aircraft *БИ-1* in 1934) and V. M. Rastorguyev (aboard a *Як-3* aircraft powered by an *РД-IX3* liquid-propellant engine in 1945), and many others. The first victims of space flight after the space age began were the American astronauts V. GRISSOM, E. WHITE and R. CHAFFEE, who perished on January 27, 1967, aboard their spaceship in a fire that broke out during ground tests of the *Apollo-Saturn-1B* space vehicle at the Eastern Test Range, Cape Kennedy. On April 24, 1967, the Soviet Pilot-Cosmonaut M. KOMAROV perished while landing the *Soyuz-1* upon his return from a space flight. These accidents were preceded by successful flights of 31 Soviet and American spacemen aboard 22 spaceships within the period from 1961 to 1966.

VIEWING PORT. An airtight window in spaceship cabin. It is usually round, intended for observing the surrounding space, as well as for navigation, orientation, and taking photographs and motion pictures. The viewing ports of re-entry bodies are made of special heat-resistant glass.

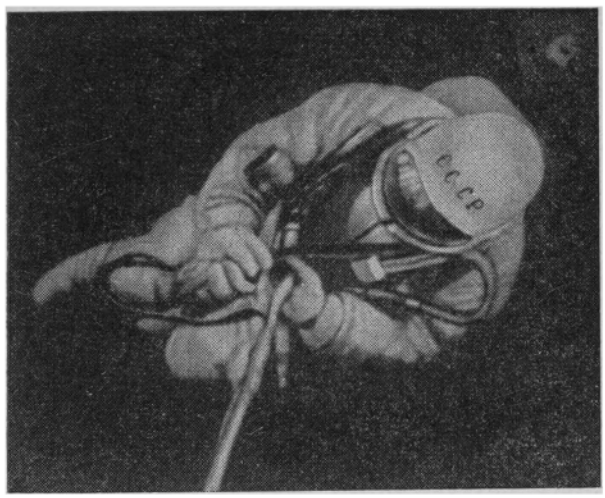
VOLUME SPECIFIC IMPULSE. A parameter numerically equal to the product of the engine's specific impulse by the propellant density. It characterises the power recovery of a volume unit of propellant.

VOLUMETRIC THRUST. The THRUST OF ROCKET ENGINE in relation to the working volume of the combustion chamber. It is measured in kg/l and characterises the power rating of the engine. Not used at present.

VOLYNOV, Boris Valentinovich (born 1934, Irkutsk). Pilot-Cosmonaut of the USSR. Colonel. Hero of the Soviet Union. Member of the CPSU since 1958. Graduated from secondary school in Prokopyevsk and the Volgograd Air Force School. Joined the Soviet Air Force in 1957. Was enlisted in the group of cosmonauts in 1960. Graduated from the correspondence course of the Zhukovsky Air Force Engineering Academy. On January 15—19, 1969, made a space flight as command pilot of the *Soyuz-5* which carried Cosmonauts A. S. Yeliseyev and Ye. V. Khrunov into circumterrestrial orbit. B. V. Volynov and V. A. Shatalov carried out an experiment in approach and docking of the *Soyuz-4* and *Soyuz-5* making it possible for Yeliseyev and Khrunov to pass through open space into the *Soyuz-4*. During his space flight which lasted 72 h 46 min, Volynov circled the Earth 49 times, covering 2,000,000 km.

VOSKHOD. The name of a series of Soviet multi-seater spaceships for circumterrestrial flight.

Voskhod. Three-man spaceship placed in orbit on October 12, 1964. It weighed 5320 kg. The crew consisted of Pilot-Cosmonaut V. M. Komarov, the command pilot, researcher-cosmonaut K. P. Feoktistov, and physician-cosmonaut B. B. Yegorov. This flight continued for 24 h 17 min in



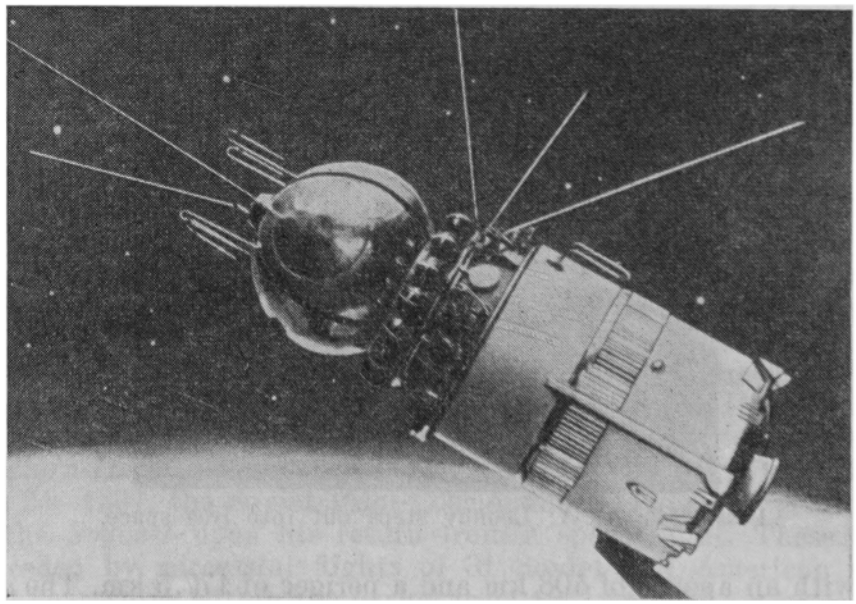
Voskhod-2. A. A. Leonov steps out into free space.

an orbit with an apogee of 408 km and a perigee of 177.5 km. The spaceship landed on October 13, 1964, 312 km northeast of Kustanai. The *Voskhod* differs from the *Vostok* spaceships in both structure and equipment. It was provided with a SOFT-LANDING system, a redundant retro-rocket engine, new instrumentation (additional orientation system with ionic sensors, advanced TV and radio communication equipment, etc.). The objects of this mission were to test the new multi-seater spaceship, to investigate the work capacity of a group of spacemen specialized in different spheres of science and engineering, to make physical and technical experiments, and to perform an extensive medico-biological investigation programme. This mission was completely fulfilled and a large amount of scientific data was obtained.

Voskhod-2. A two-man spaceship provided with an air lock and equipment for man's exit into free space. It was placed in orbit on March 18, 1965; the flight duration was 26 h. The orbit parameters were: perigee 173 km, apogee 495 km. The crew consisted of Pilot-Cosmonaut P. I. Belyayev, command pilot, and Pilot-Cosmonaut A. A. Leonov, co-pilot. During this flight A. A. Leonov wearing a space suit with self-contained LSS left the spaceship and became the first man in history to step out into space and stay there for 20 min, sometimes up to 5 m away from the spaceship. This was practical proof that a spaceman in a space suit could leave his ship and work outside of it. Leonov's exit and movements in free space were shot with movie cameras mounted inside the air lock and outside the spaceship. The *Voskhod-2* was landed with manual control in the vicinity of Perm on March 19.

VOSTOK. The name of a Soviet one-man spaceship series for near-Earth orbits, in which Soviet spacemen made their first flights.

Vostok was the first spaceship in history to carry man into space. Piloted by Yu. A. Gagarin it was launched from the Baikonur space centre on April 12, 1961 at 9 h 07 min, Moscow time. After completing one orbit, it



Vostok (general view).

landed at 10 h 55 min near the village of Smelovka, Saratov Region. Its orbit had a perigee of 181 km and an apogee of 327 km. The *Vostok* spaceship comprises a re-entry body which houses the manned cabin, an instrument compartment, and a retro-rocket engine. The combined weight of the last stage of the launch vehicle and the spaceship is 6.17 t, the length 7.35 m; the weight without the last stage is 4.73 t, while the re-entry body weighs 2.4 t and has a dia of 2.3 m. The spaceman wearing a space suit, sits in an

ejection seat. The ship has automatic and manual control. The LSS is designed for 10-days operation. Radio communication with Earth is maintained continuously. To accomplish the landing, the retro-rocket engine is fired to reduce the spaceship's speed and place it on the descent trajectory. Following this, the re-entry body is separated; after sufficient braking in

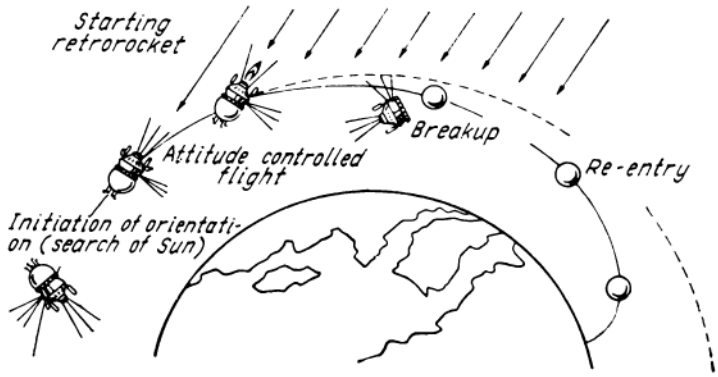
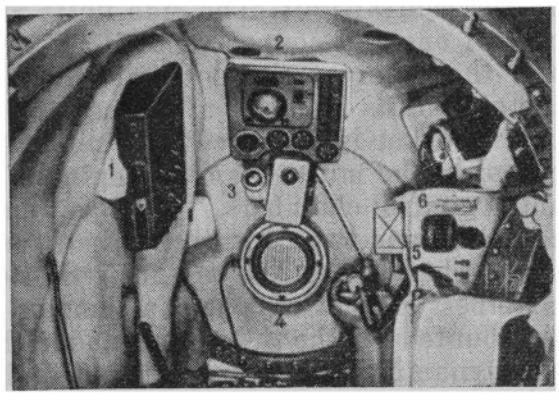


Diagram of descent of the *Vostok* spaceship from orbit.

the Earth's atmosphere, at a height of 7 km, the spaceman is ejected from the cabin and lands by parachute. Means are also provided for landing the spaceman in the cabin, without ejection. The first flight made by the *Vostok* confirmed that its structure and equipment were reliable and that a trained man could safely withstand injection into orbit, orbital flight, and re-entry.

Vostok-2 was placed in orbit on August 6, 1961, with Pilot-Cosmonaut G. S. Titov on board. It made 17 orbits round the Earth in 25 h and landed on August 7 near Krasny Kut, Saratov Region. The orbit had a perigee of 178 km and an apogee of 257 km. Biomedical experiments were performed and motion pictures of the Earth were taken. This flight proved that man could withstand long periods of weightlessness and provided data valuable in the preparations for future flights by Soviet spacemen.

Vostok-3 was placed in orbit on August 11, 1962, piloted by A. G. Nikolayev. After completing 64 orbits in a flight lasting about 94 h, Nikolayev landed on August 15 in the vicinity of Karkaralinsk, Karaganda Region. The orbit parameters were: perigee 180.7 km, apogee 234.6 km. *Vostok-3* together with *Vostok-4* accomplished the world's first group flight of spaceships.



Cabin of the *Vostok* spaceship.

1—spaceman's control panel; *2*—instrument board (with globe); *3*—television camera; *4*—viewing window and optical orientation device; *5*—orientation control stock; *6*—radio receiver; *7*—food containers.

Vostok-4 was placed in orbit on August 12, 1962, with Pilot-Cosmonaut P. R. Popovich on board. After orbiting 48 times in 70.7 h, the ship landed on August 15 in the vicinity of Atasu, Karaganda Region. The orbit parameters were: perigee 179.8 km, apogee 236.7 km. According to their programme, *Vostok-3* and *Vostok-4* performed the world's first group space flight, lasting 70 h 28 min. The least distance between the spaceships was about 5 km. Radio communication was maintained between the ships and with Earth. For the first time in history, TV pictures were transmitted from the spaceships to Earth and broadcast by the Soviet TV system and Intervision, this marking the beginning of SPACEVISION. A series of scientific and biomedical experiments was carried out. In weightless condition, the spacemen freely floated about within their cabins. They did not lose the capacity to work. The flights of *Vostok-3* and *Vostok-4* proved that man could withstand space flights lasting several days.

Vostok-5 was placed in orbit on June 14, 1963, with Pilot-Cosmonaut V. F. Bykovsky on board. After completing 81 orbits in 119 h this spaceship landed on June 19, 540 km northwest of Karaganda. The orbit parameters were: perigee, 181 km, apogee, 235 km. *Vostok-5* and *Vostok-6* made a group flight lasting almost 3 days.

Vostok-6 was placed in orbit on June 16, 1963, and was the first spaceship in history to be piloted by a spacewoman, V. V. Tereshkova. After completing 48 orbits in 70.7 h, this spaceship landed on June 19, 620 km northeast of Karaganda. The orbit parameters were: perigee, 183 km, apogee, 231 km. For almost 3 days *Vostok-6* flew together with *Vostok-5*, maintaining two-way radio communication. Radio communication with the Earth was established at regular intervals. The TV pictures relayed to Earth permitted the spacemen to be seen in their cabins. A series of biomedical and scientific experiments was conducted with the participation of the spaceship occupants. Useful data were obtained for further improvement of the spaceship's systems.

VOSTOK LAUNCH VEHICLE. The name for a series of Soviet three-stage rockets that were used for placing into orbit the VOSTOK spaceships. The *Vostok* rocket comprises 6 units: a central unit, 4 side ones and a 3rd stage unit. The 1st and 2nd stages are of cluster design and their division is longitudinal (see MULTISTAGE ROCKET). The cluster is composed of the central and 4 side units. The 3rd stage which is of vertical-division design is mounted on the central unit. The side units are arranged symmetrically around the central one and connected to it by two belts of power links, one at the top and the other at the bottom, which have the mechanisms for jettisoning the side units in flight after their rocket engines stop operating. Each unit of the rocket is equipped with an individual engine firing LOX and hydrocarbons. The multi-chamber engine of the central unit has 4 main chambers and 4 control chambers. The rocket engine of the side unit comprises 4 main chambers and two control chambers (see РД-107, РД-108). The 3rd stage has a single-chamber rocket engine with 4 control nozzles. The main and control chambers of each unit have a common turbopump unit. The *Vostok* spaceship is mounted on the 3rd stage, under the nose cone which protects it against aerodynamic loads acting during flight through dense layers of the atmos-

Vostok launch vehicle

phere in the launching phase. The total length of the launch vehicle is 38 m; its dia (over rudders), 10.3 m; length of the central unit, 28 m, its maximum dia, 2.95 m; length of the side unit, 19 m, its maximum dia, 3 m; length of 3rd stage together with the spaceship and the nose cone, 10 m. The payload placed into orbit (*Vostok* spaceship) is 4725 kg. Within the powered-flight phase of the 1st stage, the engines of the central and the side units work simultaneously. After burnout of the side units, their rocket engines are cut off and they are jettisoned away from the central unit. The engine of the central unit goes on operating on full-thrust duty. After the dense layers of the atmosphere are passed, the nose cone is thrown off. Some time later, after the propellant of the central unit is burnt out, the 3rd stage rocket engine is started and the stage is separated from the central unit. The 3rd stage engine is cut off and the signal for the spaceship to be separated is given by the control system when the design velocity required for placing the spaceship on the preset orbit is reached. The *Vostok* launch vehicle spells an outstanding achievement of Soviet and world rocket engineering. Its performance considerably surpasses that of any rocket made before 1964. High power and reliability of this rocket have largely contributed to the successful development of the Soviet satellite-spaceships and manned flights of the *Vostok* spaceships.

W

WASHING OPERATIONS. Removal, with the aid of water or neutralizing solutions, of rocket propellants spilled on the launch vehicle skin or on the launcher. They are performed to prevent the attack of corrosive propellants on the launch vehicle and launch equipment units and to protect the launching personnel against the toxic effect of the propellants. When the fuelling facilities are properly designed there is no need for washing operations.

WATER CONDITIONING. Processing of water recovered by the LSS to meet standards for potable water. In composition it closely resembles distilled water and contains no mineral salts or micro-elements usually contained in natural water. This water is void of organoleptic properties, has an unpleasant taste, does not quench thirst and may cause various disorders if used for a long time. Provision of spacemen with water having the necessary chemical composition and organoleptic properties is of physiological importance. The methods used in water conditioning are percolation of water preliminarily saturated with carbon dioxide through crushed marble (provides water with satisfactory organoleptic properties, but containing calcium bicarbonate only); use of filters with crushed dolomite; methods of water conditioning with enriching pellets and ion exchange resins are poorly developed as regards use in space flight. The latter methods improve the organoleptic qualities of water, but offer no means of obtaining water with the necessary chemical composition. For extended space flights the method of water conditioning by addition of concentrated solutions of salts is the most promising.

WATER ELECTROLYSIS. Decomposition of water by an electric current to obtain oxygen in spaceship LSS; is carried out in electrolyzers of the physicochemical gas regeneration systems. In space flight (under weightlessness or subgravity) the process of water electrolysis is effected in an artificial field of gravity, or by means of porous hydrophilic elements, owing to their wettability and capillarity.

WATER REGENERATION. Preparation of drinking water from moisture-containing human and other biological wastes. The sources of water are urine, sanitation water, atmospheric moisture condensate collected in the cabin, TRANSPIRATION MOISTURE excreted by plants if there is a SPACE FARM or photosynthetic reactor. Methods of water regeneration are divided into two groups: (1) methods with low energy consumption, such as sorption, filtration, coagulation, use of semi-permeable membranes and ELECTRODIALYSIS and, (2) methods with high energy consumption, such as distillation, catalytic oxidation, FREEZE DRYING, etc. Methods of the former group are used for regenerating water from liquids with low content of admixtures (atmospheric moisture condensate and transpiration moisture). Urine is processed at high temperatures in vacuum, which requires considerable power consumption. Promising for extended space flights is freeze drying making use of space vacuum, solar heat and cold on the shady side of the spaceship.

WATER STORAGE. For space flights of comparatively short duration, the necessary water supply is taken on board. Therefore reliable methods of storage, that will ensure preservation of the chemical and organoleptic properties of the water, are necessary. The water in the survival kit is also treat-

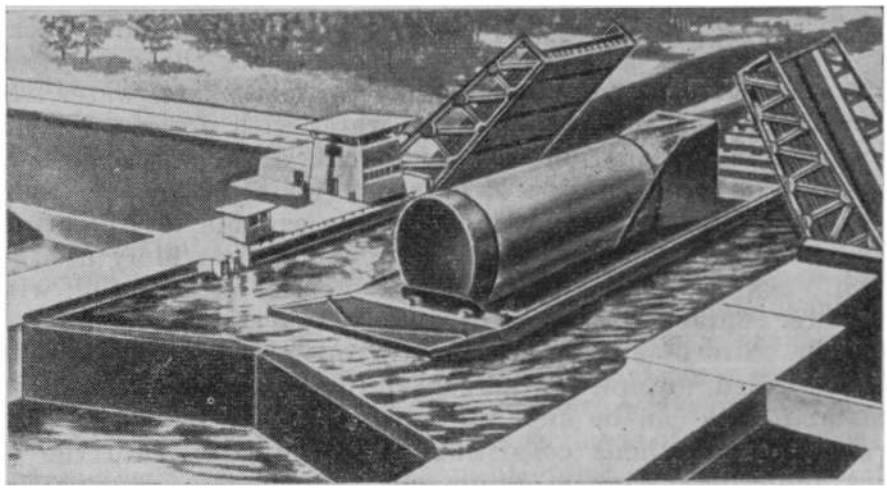
ed to preserve its properties and qualities for a long period. Water storage containers are made of materials that do not affect the properties of the water, and are pre-sterilized. There are several methods of water treatment. *Chemical* methods consist in treating the water with preservants. The most effective method is chlorination of water, but its disadvantages are difficulty of automation, impermissibility of chlorine liberation in the cabin atmosphere, inadvisability of storing preparations capable of liberating active chlorine on board a spaceship. Silver compounds are widely used (e.g., on VOSTOK and VOSKHOD spaceships). Methods of water preservation with silver compounds are: contact of water with silver-plated surfaces (contact method); use of soluble salts of silver; electrolytic introduction of silver ions into the water. Purified natural water containing small quantities of organic substances and salts can be kept up to 6 months in glass or polyethylene vessels. *Biological* methods consisting in introduction into the water of antibiotics (chloromycetin, streptomycin, aureomycin, terramycin, subtilin, etc.) cannot be recommended for long periods of storage. *Physical* methods such as irradiation or ultrasonic treatment produce a high bactericidal effect, but they require additional power consumption. Same is true of water freezing which, however, can be used in attitude-controlled spaceships (use is made of the low temperatures on their dark side).

WATER SUPPLY. During short-term space flights water is provided by the supply taken on board; extended flights require a special system for water recovery from moisture-containing biological waste of man and the BIOCOMPLEX. Water-regeneration systems in spaceships intended for 15- to 20-day flights are expedient. The sources of water recovery are urine, ATMOSPHERIC MOISTURE CONDENSATE, transpiration moisture, washings, etc. Water may be recovered by physico-chemical or biological methods, or by their combination.

WATER-WASHING UNIT. A portable, self-propelled or trailed unit intended for washing operations at the space centre. It consists of a heat-insulated tank, a water heater, a pumping plant with shut-down and control fittings, manifolds and fire hoses, a fuel tank and a motor truck chassis. The water in the tank may contain neutralizing additives, e.g., soda, in which case the water-washing unit is often called a neutralizing machine.

WATERWAYS. Used for delivering the individual stages of giant launch vehicles to the space centre. As distinct from transportation by rail, road and air, waterways impose minimum limitations on the size and weight of rockets. Waterways are used to carry rocket stages weighing over 150 t with a shell dia of over 10 m and a length exceeding 50 m. Low speed is a disadvantage of transportation by waterway.

WEIGHTLESSNESS. The gravitation of the Earth attracts man's body to the ground. In standing or sitting position gravitational force presses the body against a support and can be felt as body weight. Depending on particular conditions, the force of interaction of the body and the support may vary and differ from the normal, i.e., interaction between a stationary object and a support on the Earth's surface (at sea level). Thus, when an aircraft recovers from dive, the pilot is pressed against his seat by a force several times the force in normal conditions. When a space vehicle is in



A rocket stage transported in a barge along a canal (USA).

powered flight, the spaceman may be pressed against his seat by a force several times the normal force of gravity (acting when the rocket is on the launching pad and its engines have not been started). The ratio of the force of body-support interaction to the force of such interaction in normal conditions is termed *g-load*. In dive recovery of an aircraft or in powered flight of a rocket the g-load is greater than 1. In normal conditions the g-load is 1. This number may be less than 1, e.g., when the thrust of a space vehicle engines, at a certain moment during the flight, is less than its weight in normal conditions. If there is no interaction between a body and a support, the g-load is equal to zero. This state is called *weightlessness*. The spaceman experiences weightlessness in the cabin of a spaceship outside the atmosphere when the engines are cut off. The spaceman's body and the spaceship are effected by gravitational forces that impart equal accelerations to them. The spaceman on a space walk is also in a weightless state. In this case the force of interaction between his body and a support is zero, since there is no support at all. It is possible that in prolonged space flight lasting several months or years the state of weightlessness will adversely affect human organism. It has therefore been proposed that a certain g-load be imitated in spaceships. One suggestion is that the spaceship be designed in the shape of a wheel rotating around the axis perpendicular to the plane of the wheel. The compartments for spacemen are arranged on the periphery of the wheel. The gravity developed by the wheel's rotation is similar to that developed by a centrifuge.

WEIGHT-TO-THRUST RATIO OF ROCKET ENGINE. The ratio of weight (in kg) of a rocket engine loaded with propellant, to thrust (in tons) it develops. For engines of the 1st stage the weight is related to thrust on Earth, and for other stages, to thrust in vacuum. This ratio for modern liquid-propellant engines is 7—20 kg/t, which is much smaller than those for other types of engines. Lower weight-to-thrust ratios are possible for higher-thrust engines.

WESTERN TEST RANGE (WTR, prior to 1965— the Pacific Missile Range). A largest space centre in the USA incorporating 4 rocket ranges located on the Pacific coast. The main section of this space centre is the Vandenberg Air Force Base that occupies an area of 260 km² north of Los Angeles. The launch complexes of the WRT are located in an area with the centre at 35° 00′ N.L. and 12° 30′ W.L.

The 10,000 km range of the WTR spreads over the Pacific Ocean and can be extended to the Indian Ocean. About ten ground tracking stations equipped with optical, telemetry and radar instruments are positioned along the range. In addition, rockets are tracked by ships and aircraft.

The WTR serves for launching Earth satellites by means of *Atlas*, *Titan*, *Scout* and other launch vehicles. This space centre is capable of putting satellites into orbits with an inclination of 34.7° to 90° (for a westward launch) and of 81.8° to 90° (for an eastward launch). The firing azimuth is limited to the range of 170° to 301°. In addition to space research, the WTR is widely used for flight testing combat missiles. The Range is being continuously extended. It is planned to increase the area of the Vandenberg Air Force Base to 400 km² and the number of employees to 20,000.

WET OXIDATION. A method of mineralization based on liquid-phase oxidation of organic substances contained in metabolic by-products. Wet oxidation in acids cannot be employed, since it reqires great amounts of oxidizer, whose regeneration and recycling are very difficult. The method employed in sewage treatment can be used in closed LSS of spaceships. It is based on oxidation of organic substances in a liquid phase (usually water) at high temperatures and pressures (the optimum temperature is 200°—300°C and pressure up to 150 at). The degree of mineralization by means of wet oxidation reaches 75—85%.

WHITE, Edward (born 1930, San Antonio, Tex., died 1967, Cape Kennedy). US astronaut, lieutenant-colonel of USAF. Graduated from the US Military Academy in 1952 and from the University of Michigan in 1959. Entered the USAF and completed pilot training in Flo. and Tex. Upon graduation from the Air Force Test Pilot School at Edwards Air Force Base in 1959 served as a test pilot at an Air Force Base in Ohio. Joined the group of astronauts of the NASA in 1962. Was co-pilot in an orbital flight in the *Gemini-4* spaceship together with J. McDivitt on June 3, 1965. In the course of this flight E. White was the first American to walk in space for 20 min. Perished on January 27, 1967, when fire broke out in the capsule of *Apollo* spaceship during tests on the launching pad.

WIND ANCHORAGE. A complex of devices and appliances intended to keep the launch vehicle firmly in position on the launcher in the course of pre-launch preparation under the action of the maximum operational wind (i.e., the wind still permitting the space vehicle to be launched). The wind anchorage is most needed by empty space vehicles erected on the launch stand. The wind anchorage may take the form of wind grabs, braces, etc., installed after erection of the space vehicle on the launcher and removed before the launch. The anchorage devices are actuated by remote-controlled systems. Frequently the elements of the wind and STORM ANCHORAGE are united into a single structure.

Wind grips

WIND GRIPS. Grips for reliable fixation of SERVICE TOWERS or trusses to rail tracks when subject to considerable wind loads in the vicinity of the launcher or in any other area of the space centre the service tower may be in. A wind grip consists of two pressure levers whose blocks are pressed against the side of the rail by strong springs or weight-lever devices. The grips are disengaged by electrical magnets or hydraulic cylinders. At disconnection from power supply, the grips operate automatically and keep the service tower in a fixed position.

WIND LOAD. Aerodynamic load on structures and buildings of the launch complex and on the launch vehicle during pre-launch preparation, arising due to the effect of ground wind. Measured by the value of wind pressure or by a concentrated force applied at the wind pressure centre of a unit or part thereof. The wind load exerts a static effect on the structures and buildings and causes them to vibrate longitudinally with and transversely to the direction of the wind. The transversal vibrations are caused by alternating separations of the air swirls from the structure surface subjected to the wind effect and depend on the ratio of the separation frequency to the natural vibration frequency of the structure or the part thereof.

WIND PROTECTION. Protection of the launch vehicle, ground support equipment and employees of a space centre from the direct effect of wind loads. The work sites of service plants are the most frequently protected; the wind barriers quite often form a closed area within which a microclimate is provided. Sometimes the wind barriers protecting circular work platforms join to make a full-height protective cover around the launch vehicle.

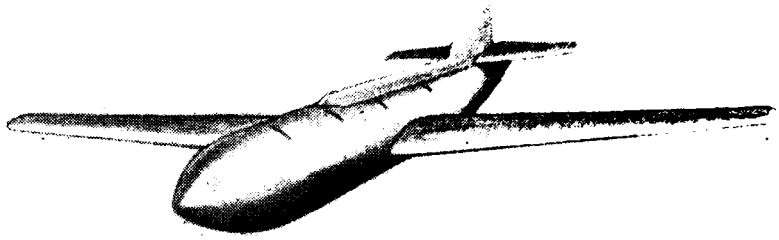
WINDS IN IONOSPHERE. Normally existing in the IONOSPHERE worldwide movement of neutral masses of the atmosphere (winds) and ionized particles in it (drifts). The horizontal velocities of the winds and drifts vary from $\sim$5 to 300—400 m/s and depend on the magnetic activity, the time of day, and the geomagnetic latitude; the direction and magnitude of the velocity of the drift of ionized particles may differ from those of the neutral component because of the effect, in particular, of the Earth's magnetic field. In the lower part of the ionosphere (at a height of 70—100 km, the so-called meteoric region) and in the *E* region (the so-called dynamo region) up to heights of about 150 km, the ionized components is entrained by the neutral one. At these heights the velocity of the wind equals 60—80 m/s and has a predominantly half-day component of movement. In the *F* region the velocity of drifts is of the order of 80—100 m/s and in middle latitudes is directed chiefly eastward and towards the poles, at night westward and towards the equator; while in the near-equatorial region (south of the 35° geomagnetic latitude) — in the reverse direction. In the vertical direction (along the height) the velocity of the winds and drifts is much smaller than the horizontal velocities; it is of the order of 5—15 m/s and displays pronounced dependence on the day-night effect. The presence of wind and drift systems causes systematic changes in the Earth's magnetic field and affects the latitudinal and longitudinal distribution of electron concentration in the ionosphere.

WINDS IN UPPER ATMOSPHERE. The ever present motion of air whose character varies with height. The large-scale mean motion of air masses

is called circulation. The atmospheric circulation at altitudes from 30 km to the MESOPAUSE (~85 km) is basically latitudinal; in summer, winds have a westerly mean direction, while in winter their mean direction is easterly, and speed somewhat higher. The change from one type of circulation to another is relatively rapid. Maximum velocities are observed in middle latitudes near the MESOPEAK and reach 60—90 m/s at 80—100 km. Winds are studied by measuring the paths of falling spheres, the speed of sound, the drift of meteoric wakes, and the space-time variations of emission intensities, as well as by dispersal of artificial luminescent sodium clouds and by observation of noctilucent clouds. According to data obtained by studying drift of meteor wakes, the prevailing wind velocity is 15 m/s, the winds being north-westerly in summer and westerly in winter, while in the spring and autumn weak easterlies prevail. It is possible that the mean wind distribution in the Southern Hemisphere differs from the above. Also, regular diurnal variations in wind direction and velocity have been found to exist. An instantaneous picture of the winds shows that frequently there is motion in different directions at velocities from 5 to 400 m/s. The speed of vertical motion is far smaller and does not exceed the order of 1—10 cm/s. Particularly sudden variations exist within the 100—110-km region where moving neutral particles carry along ions (but have no apparent influence on the electrons). In this so-called dynamo-region, the motion of neutral particles can produce a mean motion of ions with respect to electrons, i.e., an electric current which, in turn, produces geomagnetic variations. The appearance of electric fields in the upper atmosphere due to the movement of neutral particles caused by the wind should lead to other interesting consequences, e.g. changes in the trajectories of particles of radiation belts, disturbances in the ionosphere and, probably, even to the formation of thin sporadic layers of the ionosphere. The flow of neutral particles from the sunlit region where temperature and density are higher into the cooler dark region predominates at high altitudes, especially in the THERMOPAUSE. However, dissipation decreases the helium and, especially, hydrogen concentration on the sunlit side of the Earth, thus giving rise to the horizontal flow of these gases from the nocturnal to the diurnal side. In the higher altitudes the motion of ions is, practically, no longer influenced by their collisions with neutral particles, since the ions are bound to the magnetic field; however, they noticeably decelerate the neutral particles. For this reason wind velocity should decrease where ion concentration in the ionosphere increases. The asymmetry of regions of greatest heating and cooling with respect to a midday meridian, together with anomalies in the ionospheric structure, must result in rather a complicated picture of winds at thermopause heights, their velocities being 30—150 m/s. Additional local wind systems may also arise due to auroral heating during aurorae. The transfer of particles of the upper atmosphere by winds must lead to balancing of pressure, intermixing of atmospheric components and equalizing of its composition at various heights.

WINGED (AERODYNAMIC) ROCKETS. A series of experimental rockets developed in 1934—1938 by the Rocket Research Institute under S. P. Korolev (rockets *212*, *201*, *216* and *217*). Rocket *212* was a ground-to-ground guided rocket powered by an *OPM-65* liquid-propellant engine;

it was a midwing monoplane with a tapered wing. It was 3 m long and had a take-off weight of 210 kg, including 30 kg of propellant (nitric acid and kerosene) and a 30-kg payload. Its design range was 50 km. The rocket had



212 winged rocket.

an automatic gyrostabilizer and flight guidance. Launching was accomplished by a powder-powered rocket catapult from a track. The first flight took place on January 29, 1939.

WOOMERA MISSILE RANGE (WMR). The Anglo-Australian missile test range in Southern Australia near the town of Woomera. The 2000-km ground range of the WMR passes over scarcely-populated regions of Australia and can be extended, if necessary, by 4400 km into the Indian Ocean. The range is used for experimental launching of the British *Blue Streak* launch vehicle and the *Europa* rocket developed by the European Launcher Development Organization (ELDO), as well as for launching probes into the upper strata of the atmosphere. The basic proportion of the range experiments falls to the share of combat missiles. Almost all of the British missiles are tested there. USA and some other NATO countries are admitted, too.

The WMR has 6 launch pads and over 200 measuring posts located along the range. Two telemetry systems are provided, one of which is a 24-channel system with antennas automatically tracking missiles, the other is used for launching space vehicles.

Out of the 6000 employees of the WMR some 1000 men are engaged constantly at the launch pads. The yearly operating costs of the range rise as high as $45 million. The management body of the range is the Weapons Research Establishment, Salisbury, Australia.

WORKING FLUID of rocket engine. The substances which undergo various physical and chemical transformations constituting the working process in a rocket engine. A working substance, that is also the source of energy, is called a rocket PROPELLANT. In this case the principal stages in the transformations in the rocket engine are as follows: propellant—burning mixture—combustion products—jet efflux. In some rocket engines the energy e.g., heat in nuclear rocket engines, electrical energy in electrical rocket engines, is supplied to the working fluid from outside sources. The principal stages

in the transformation of the working fluid in these engines will be, respectively: condensed fluid—products of heating—jet efflux; and: condensed working fluid—products of gasifications or crushing of the fluid—ionization products—jet efflux. In all the cases, the flow of the working fluid finally gives rise to the force of reaction, i.e., the thrust of the rocket engine. Used as the source of working fluid for rocket engines, besides the propellant, can be condensed substances, usually of low molecular weight, e.g., liquid hydrogen for heat engines (nuclear rocket engines); liquid metals (cesium, rubidium, mercury and others) or organic compounds (see COLLOID ROCKET ENGINES) for electrical rocket engines. In hypothetical PHOTON ROCKET ENGINES the final stage in the transformations of the working fluid are photons.

Working process

WORKING PROCESS of rocket engine. A complex of consecutive systematic physico-chemical changes in the rocket engine's WORKING FLUID, which result in thrust development. The perfection of the working process determines the thrust and efficiency of a rocket engine.

Y

YANTAR-1. The name of a Soviet automatic ionospheric laboratory launched by a geophysical rocket in October 1966 to study the interaction of the jet efflux of an electric rocket engine and the spacecraft in the ionosphere. The maximum height attained was 400 km; an experimental electric rocket engine of the plasma-ion type was ignited at an altitude of 160 km to be followed by 11 more running cycles. The jet velocity ~40 km/s was recorded. The data on the interaction of the jet and ionospheric plasma, obtained during this experiment, are of great significance in the solution of problems of controlled flight of a vehicle with electric rocket propulsion in the upper atmosphere at altitudes of 100 km and over.

YEAR. The unit of time equal to the period of one revolution of the Earth round the Sun, or the period during which the Sun seems to complete a circle around the CELESTIAL SPHERE. The period of one revolution with respect to any star is called a *sidereal* year (365.2564 mean solar days). The period from VERNAL EQUINOX to vernal equinox is called a *tropical* year (365.2422 mean solar days). The period of revolution from PERIHELION to perihelion is an *anomalistic* year (365.2596 mean solar days). The interval between two successive conjunctions of the Sun with the same node of the Moon's orbit is called a *draconic* year (346.6201 mean solar days). The calendar years are the Julian (365.2500 mean solar days) and the Gregorian (365.2425 mean solar days). To compensate for the difference between true and calendar time every 4-year period includes common years having 365 days (28 days in February) and a leap year of 366 days (29 days in February). Each year whose number is exactly divisible by 4 is called a leap year, except century years (1800, 1900, etc.) which must be exactly divisible by 400 (2000, 2400, etc.).

YEASTS. A family of unicellular microscopic fungi. The yeasts BIOMASS contains proteins, fats, carbohydrates and vitamins that are easily assimilated. Yeasts can be used in biotechnical systems of spaceships for partial regeneration of food and utilization of vegetable wastes.

YEGOROV, Boris Borisovich (borh 1937, Moscow). Pilot-cosmonaut of the USSR. Physician. Candidate of Medical Sciences. Hero of the Soviet Union. After graduation from the First Moscow Medical Institute in 1961, he worked in medical research institutions. On October 12, 1964, together with V. M. KOMAROV and K. P. FEOKTISTOV, B. B. Yegorov made a space flight in the *Voskhod* multi-seater spaceship.

YELISEYEV, Alexei Stanislavovich (born 1934. Zhizdra, Kaluga Region). Pilot-cosmonaut of the USSR. Candidate of technical sciences. Hero of the Soviet Union. Member of CPSU since 1967. Graduated from a secondary school and the Bauman Moscow Higher Technical School (MVTU). Beginning 1957 worked at a design office, and after 1966 combined this work with training in the group of cosmonauts. Presented and defended his candidate's thesis in 1967. On January 15—17, 1969, made a space flight leaving the Earth as the space engineer on board the *Soyuz*-5 piloted by cosmonaut B. Y. Volynov. On January 17, A. S. Yeliseyev and Cosmonaut B. V. Khrunov passed through open space into the *Soyuz-4* piloted by Cosmonaut V. A. Shatalov and returned to the Earth in the latter spaceship. Yeliseyev made 32 revolutions around the Earth, covering 1,300,000 km in 47 h 39 min, including 37 min open space.

YOUNG, John Watts (born 1930, San Francisco). US astronaut. USNavy commander. After graduation from the Institute of Technology, Atlanta, Ga., in 1952 served in the Navy. Test pilot in 1959—62. In 1962, he set the world time-to-climb flight records for 3 and 25 km with a Navy fighter. Joined the group of astronauts of the NASA in 1962. Made an orbital flight as co-pilot of the *Gemini-3* together with V. GRISSOM on March 23, 1965, and circled the Earth 3 times in 5 h. He commanded the *Gemini-10* in a flight made with M. COLLINS on July 18, 1966; the spaceship orbited Earth 43 times in 71 h and covered a distance of ~1,600,000 km. During this flight *Gemini-10* docked with the *Agena-10* target rocket, and the engines of the latter were used to change the orbit of *Gemini-10*. After separation from *Agena-10*, *Gemini-10* had a rendezvous with the *Agena-8* target rocket. Was a crew member of *Apollo-10* carrying also T. Stafford and E. Cernan in flight on May 18—26, 1969; the ship went into circumlunar orbit on May 21. After 61 h 40 min of revolving around the Moon, during the 32nd orbit, the spaceship changed into trans-Earth trajectory. The flight mission included debugging of spaceborne systems and scientific investigations.

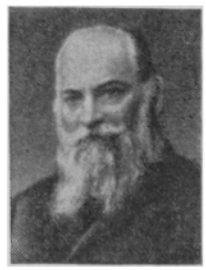
Z

ZASYADKO, Alexander Dmitrievich (1779—1837). Lieutenant-general of Russian army, researcher and artillerist, designer of gunpowder war rockets. Began designing various types of war rockets in 1814, and by 1817 he was able to demonstrate rockets in St. Petersburg, that reached a range of 2670 m. The rockets were manufactured at a pyrotechnical laboratory that Zasyadko organized in Mogilev. The work done by Zasyadko and other inventors led to the setting up of a permanent rocket establishment in St. Petersburg in 1826, whose purpose was mass production of rockets for the Russian army

ZENITH. The overhead point in which the CELESTIAL SPHERE is crossed by the plumb line extended up from the observation post on the Earth.

ZENITH DISTANCE. A coordinate in the horizon system of CELESTIAL COORDINATES; the angular distance of a celestial body from the zenith measured by the arc of a VERTICAL CIRCLE intercepted between the object and the zenith.

ZHUKOVSKY, Nikolai Yegorovich (1847—1921). Russian scientist, founder of modern aerodynamics and hydrodynamics; V. I. Lenin called him the "father of Russian aviation". A graduate of Moscow University (1868), he taught at the Moscow Higher Technical School (MVTU) beginning with 1872 and was simultaneously a professor of Moscow University beginning with 1886. Elected a Corresponding Member of the St. Petersburg Academy of Sciences, 1894, he was offered the title of academician in 1900, but refused to accept the honour having no desire to give up teaching in Moscow.

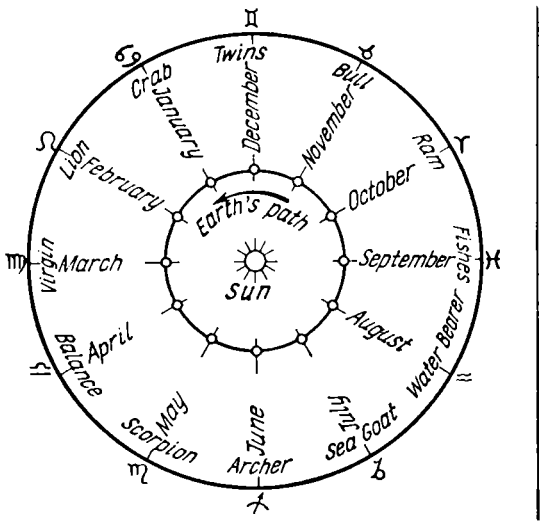


Zhukovsky supervised the construction of one of the world's first wind tunnels in 1902; he founded Europe's first institute of aerodynamics in 1904, and in 1910 the laboratory of aerodynamics at the MVTU. In 1918, Zhukovsky was chosen to head the Central Aero-Hydrodynamics Institute (TsAGI) organized by the Soviet government.

Zhukovsky's works in the field of aerodynamics and aviation were the source of principal ideas on which the science of space flight is based. He made a thorough investigation of the dynamics of the flight of birds (1891), theoretically forecast a number of possible trajectories of flight, in particular, the loop-the-loop. In 1904, Zhukovsky discovered the law governing airfoil lift (published in 1906); he developed the optimum profiles of airfoils and propeller blades (1910—1911), elaborated the theory of propeller-tip vortex (1912—1918) and other problems. Zhukovsky wrote a number of important papers on hydraulics and hydrodynamics, theoretical mechanics,

astronomy, and mathematics. Directly concerning reactive propulsion are the articles: *O reaktsii vytekayshchei i vtekayushchei zhidkosti* (*The Reaction of Outgoing and Incoming Fluid*, 1882—1885), *O dvizhenii tverdogo tela, imeyushchego polosti, napolnennye odnorodnoy kapelnoi zhidkostyu* (*The Motion of a Solid Body Provided with Cavities Filled with Homogeneous Pulverized Liquid*, 1885), and *K teorii sudov, privodimykh v dvizhenie siloi reaktsii vody* (*The Theory of Vessels Driven by Water Reaction Force*, 1908).

ZODIAC. The 12 constellations through which the Sun appears to pass in its annual motion.



Apparent motion of the Sun along zodiac and actual motion of the Earth around the Sun.

ZOND. The name of Soviet automatic interplanetary stations launched beginning 1964 with the missions of studying space and for deep-space flight technology development tests. The *Zond-1*, *Zond-2* and *Zond-3* stations each weighed ~950 kg; they had astro-orientation systems (with the Sun, the Earth and the star Canopus as reference points) and vernier engines; energy was supplied by solar batteries; the temperature control system was designed to operate at various distances from the Sun. The upper stage of the launch vehicle, carrying the interplanetary station, started from a geocentric parking orbit.

Zond-1 was launched April 2, 1964, for flight tests of the space vehicle (launch vehicle and automatic interplanetary station) for long-range interplanetary travels. 2 trajectory corrections were performed (at 560,000 km and 14,000,000 km from the Earth). A large amount of scientific information and data on operation of space-borne systems was obtained.

Zond-2 was launched November 30, 1964, in the direction of Mars to flight-test space-borne systems and to carry out scientific investigations. It carried 6 electric rocket engines of plasma type which served as actuators of the attitude control system.

Zond-3 launched July 18, 1965, in the direction of the Moon. The scientific package included a TV system providing automatic in-flight film processing (focal length of the lens: 106 mm; film width: 25 mm; number of lines in TV frame: 1100; maximum distance of TV transmission: several hundred million km). On July 20, during the Moon fly-by, photographs of the far side of the Moon were taken at distances of 11,570—9960 km; the 25 photographs, received covered 19,000,000 km^2 of the lunar surface including more than 10,000,000 km^2 which the *Luna-3* station had failed to photograph. The images were transmitted by *Zond-3* from a distance of 2,200,000 km from the Earth and the transmission was repeated from a distance of 31,500,000 km.

The images are distinguished for high quality and provide minute details of the relief of the far side of the Moon. After the Moon fly-by, *Zond-3* continued space exploration on a heliocentric orbit.

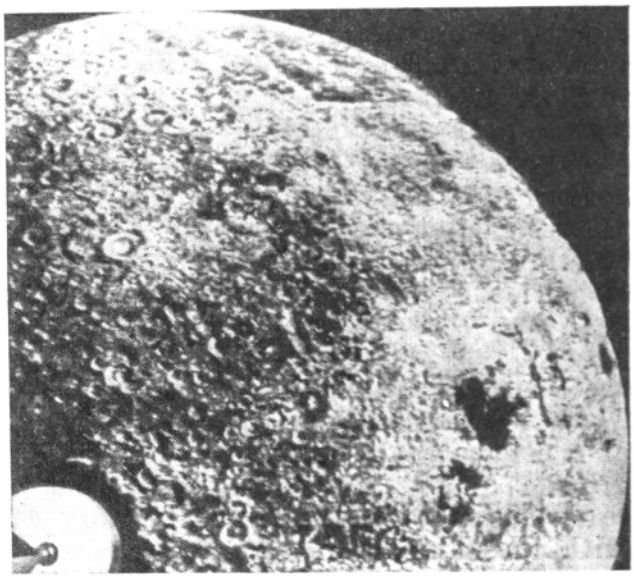


Photo of the far side of the Moon taken by the *Zond-3* automatic interplanetary station.

Zond-4 was launched March 2, 1968, for exploration of distant regions of circumterrestrial space and flight testing of new systems and equipment on board the automatic station.

Zond-5 was launched September 15, 1968, to make scientific probes on a Moon fly-by and return to the Earth at second cosmic velocity. The upper stage of the launch vehicle carrying the automatic interplanetary station started from a geocentric parking orbit (perigee: 187 km; apogee: 219 km).

The station comprised a re-entry body with thermal-protection coating, an instrument compartment accommodating the major space-borne systems (radio communication, telemetry, attitude control and stabilization, energy supply, and temperature control), and correction engines. The active system of attitude control incorporated optical transducers (Sun sensors and Earth sensors) and a system of low-thrust vernier engines. Energy was supplied to space-borne equipment from solar batteries deployed in flight. The re-entry body housed the scientific package, a camera, radio and telemetry equipment, re-entry control system, and a parachute system.

The first trajectory correction was made at 325,000 km from the Earth. On September 18, *Zond-5* flew round the Moon, at a minimum distance of 1950 km from its surface. On the return trip to the Earth, the trajectory was corrected again, which ensured the stations passage into the re-entry corridor (35—45 km wide at the altitude of the arbitrary perigee); photos

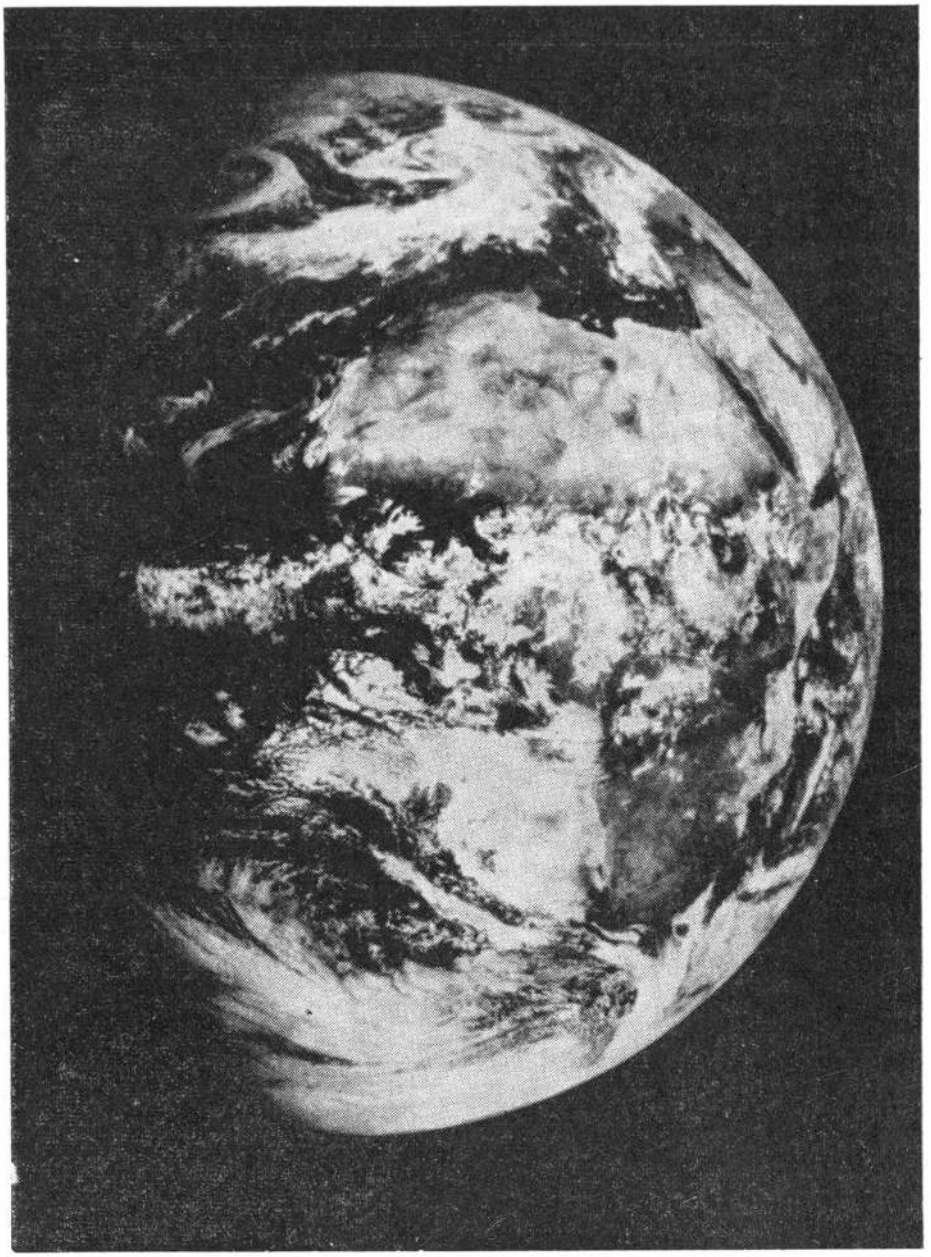
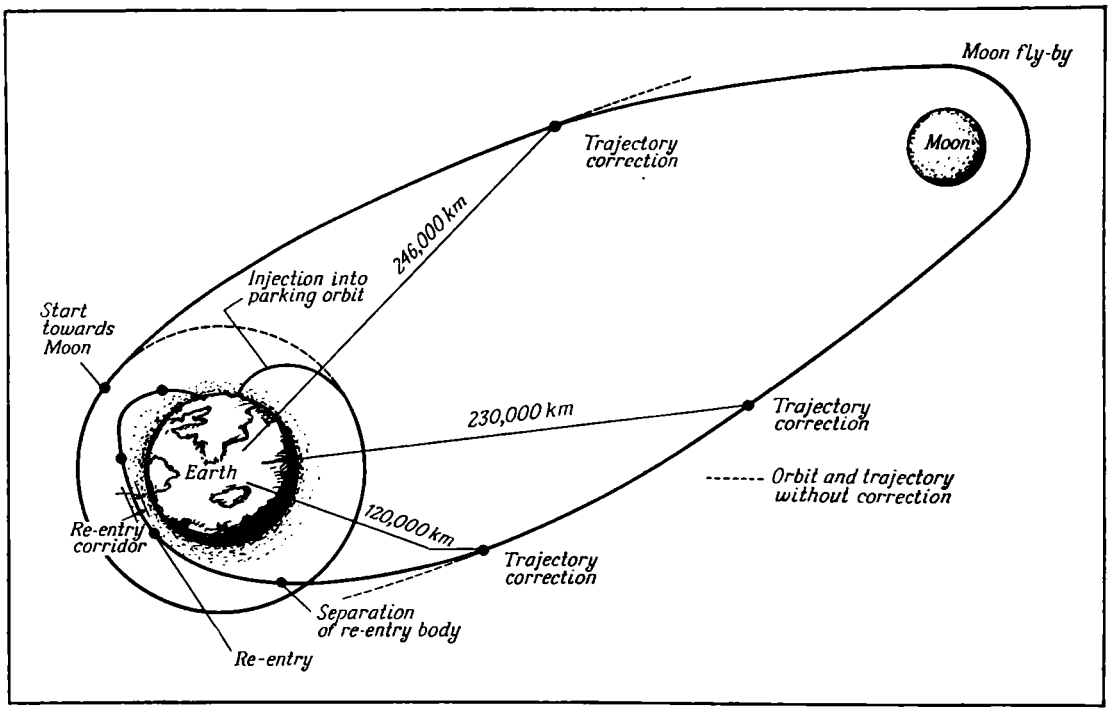
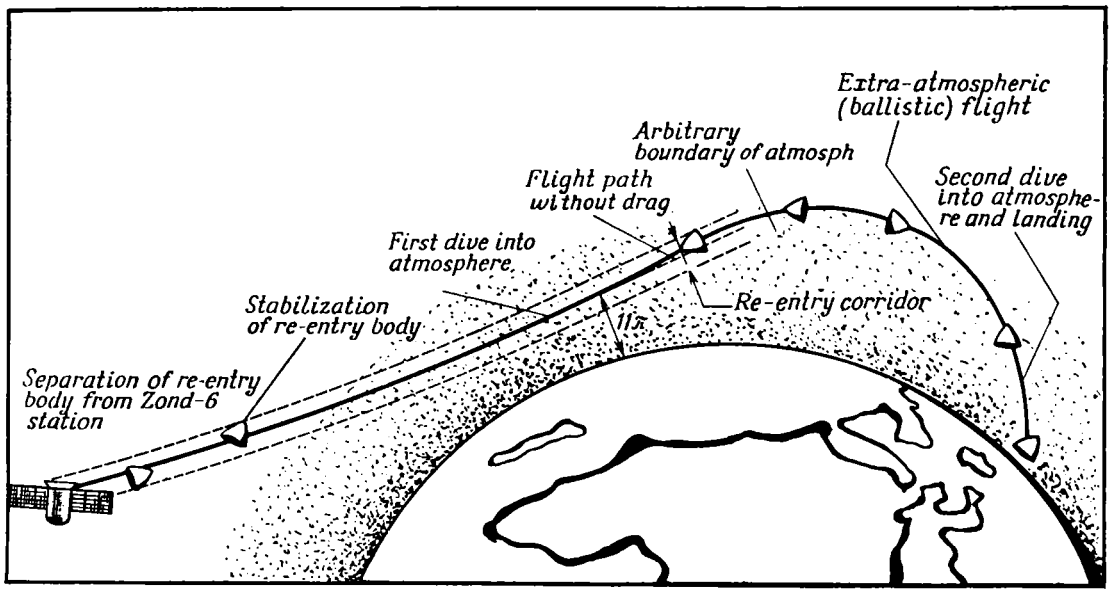


Photo of the Earth taken by *Zond-5* on September 21, 1968, when at a distance of ~90,000 km.



Flight diagram of *Zond-6* automatic interplanetary station.



Manoeuvring of *Zond-6* re-entry body in Earth atmosphere.

of the Earth were taken at a distance of 90,000 km. On September 21, the re-entry body plunged into the Earth's atmosphere and splashed down in the Indian Ocean at 32° 38′ S. Lat., 65° 33′ E. Long. The station descended along a ballistic trajectory; parachutes were deployed at an altitude of 7 km. This was the first time that a spacecraft returned to the Earth at second cosmic velocity after a flight round the Moon.

Zond-6 was launched November 10, 1968, on a Moon fly-by mission for scientific probes and controlled re-entry on return to the Earth. The design and flight pattern (except re-entry) of this spacecraft was similar to those of *Zond-5*.

On November 14, *Zond-6* flew around the Moon at a minimum distance of 2420 km. Comprehensive exploration of circumlunar space was performed and photographs taken from distances of ~11,000 km and 3300 km. The return trajectory was twice corrected to ensure precise passage of the spacecraft into the re-entry corridor. The descent trajectory, ~9000 km long, included the first dive which decelerated the vehicle to 7.6 km/s, extra-atmospheric flight along the ballastic trajectory, and the second dive during which the vehicle was decelerated to ~200 m/s. Motion along the

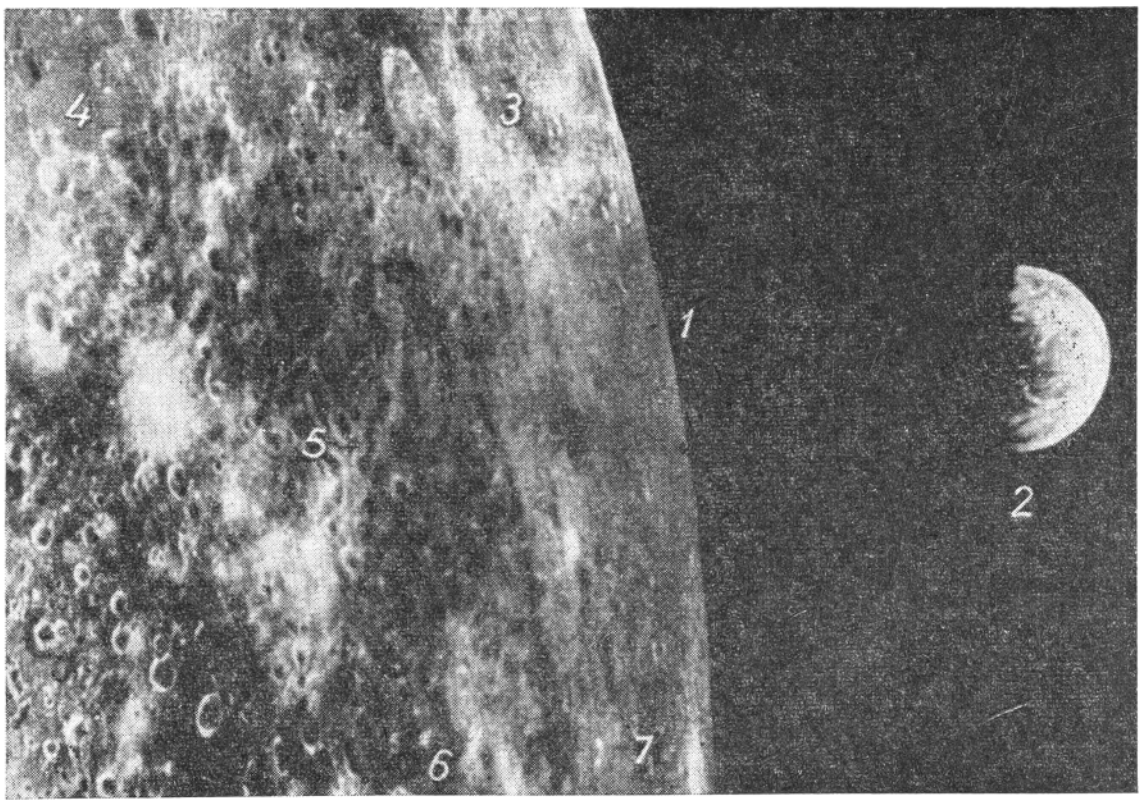


Photo of edge of the Moon and planet Earth taken by *Zond-6* automatic interplanetary station at approximately 388,000 km from Earth

1—edge of Moon; *2*—Earth; *3*—Sternberg; *4*—Lorentz; *5*—Langevin; *6*—Rynin; *7*—Buffon.

Zond

re-entry trajectory was controlled by a special system which changed the lift force by varying the roll of the re-entry body. The deceleration did not exceed 4—7 g. On November 17, the re-entry body landed in the pre-determined region of the Soviet Union.

The flight yielded a large amount of scientific information, including photographs of the lunar surface; it tested the spaceborne systems and aerodynamically lifted re-entry body. *Zond-4*, *Zond-5* and *Zond-6* automatic interplanetary stations were launched for flight testing and further development of an automatic version of a manned lunar spaceship.

APPENDIX I

MAIN ABBREVIATIONS USED IN THE TABLE

Anna — Army, Navy, NASA, AF
ATDA — Augmented Target Docking Adapter
ATS — Application Technological Satellite
Bios — Biological Investigation of Space
DME — Direct Measurement Explorer
Dodge — Department of Defence Gravity Experiment
EGRS (Secor) — Engineering Satellite
ERS — Environment Research Satellite
ESRO — European Space Research Organization
ESSA — Environmental Science Services Administration
GGSE — Gravity Gradient Satellite Experiment
GGTS — Gravity Gradient Test Satellite
HEOS — Highly Elliptical Orbit Satellite
IDCSP — Interim Defence Communication Satellite Program
IMP — Interplanetary Monitoring Probe
Intelsat — International Telecommunicaton Satellite
IQSY — International Quiet Sun Year
IRIS — International Radiation Investigation Satellite
ISIS — International Satellite for Ionosphere Studies
LEM — Lunar Excursion Module
LES — Lincoln Experimental Satellite
Lofti — Low Frequency Transionospheric
Midas — Military Defence Alarm Satellite
MOL — Manned Orbital Laboratory
OAO — Orbital Astronomical Observatory
OGO — Orbital Geophysical Observatory
ORS — Octahedral Research Satellite
Oscar — Orbital Satellite Carrying Amateur Radio
OSO — Orbital Solar Observatory
OV — Orbital Vehicle
Pageos — Passive Geodesic Earth Orbiting Satellite
REP — Rendezvous Evaluation Pot
Samos — Satellite and Missile Obvervation System
Score — Signal Communication Orbit Relay Experiment
Secor — Sequential Collation of Range
SNAP — Space Nuclear Auxiliary Power
SR — Solar Radiation
Starad — Starfish Radiation
Surcal — Surveillance Calibration
Syncom — Synchronous Communication
Tiros — Television Infrared Obvervation Satellite
Traac — Transit Research and Attitude Control
TRS — Tetrahedral Research Satellite
TTS — Test and Training Satellite
WRESAT — Weapons Research Establishment Satellite

Appendix 1

SPACECRAFT LAUNCHED IN 1957—1969

(ACCORDING TO *BULLETIN OF STATIONS FOR OPTICAL OBSERVATIONS OF ARTIFICIAL EARTH SATELLITES* ISSUED BY ASTRONOMICAL COUNCIL OF THE USSR ACADEMY OF SCIENCES, AND TABLES PUBLISHED BY ROYAL AIRCRAFT ESTABLISHMENT, UK)

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
1	USSR	Sputnik-I	1957α2	4.10.1957	2
2	USSR	Sputnik-II	1957β1	3.11.1957	1
3	USA	Explorer-1	1958α	1.2.1958	—
4	USA	Vanguard-1	1958β2	17.3.1958	2
5	USA	Explorer-3	1958γ	26.3.1958	—
6	USSR	Sputnik-III	1958δ2	15.5.1958	4
7	USA	Explorer-4	1958ε	26.7.1958	—
8	USA	Pioneer-1	1958η	11.10.1958	—
9	USA	Pioneer-3	1958θ	6.12.1958	—
10	USA	Atlas-Score	1958ζ	18.12.1958	—
11	USSR	Luna-1	1959μ	2.1.1959	2
12	USA	Vanguard-2	1959α1	17.2.1959	1
13	USA	Discoverer-1	1959β	28.2.1959	—
14	USA	Pioneer-4	1959ν	3.3.1959	1
15	USA	Discoverer-2	1959γ	13.4.1959	—
16	USA	Explorer-6	1959δ1	7.8.1959	1
17	USA	Discoverer-5	1959ε1	13.8.1959	1
18	USA	Discoverer-6	1959ζ	19.8.1959	—
19	USSR	Luna-2	1959ξ	12.9.1959	2
20	USA	Vanguard-3	1959η	18.9.1959	—
21	USSR	Luna-3	1959θ	4.10.1959	—
22	USA	Explorer-7	1959ι1	13.10.1959	1
23	USA	Discoverer-7	1959κ	7.11.1959	—
24	USA	Discoverer-8	1959λ	20.11.1959	—
25	USA	Pioneer-5	1960α1	11.3.1960	1
26	USA	Tiros-1	1960β2	1.4.1960	3
27	USA	Transit-1B	1960γ2	13.4.1960	3
28	USA	Discoverer-11	1960δ	15.4.1960	—
29	USSR	First spaceship	1960ε2	15.5.1960	6
		Spaceship cabin	1960ε3	15.5.1960	1
30	USA	Midas-2	1960ζ1	24.5.1960	1

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
92	4.1.1958	65.1	96.17	228	947
162	14.4.1958	65.3	103.75	225	1,671
11 years	—	33.2	114.8	356	2,548
300 years	—	34.25	134.18	650	3,968
93	28.6.1958	33.38	115.7	186	2,799
692	6.4.1960	65.2	105.95	226	1,881
454	23.10.1959	50.3	110.18	263	2,213
1.76	13.10.1958	—	—	—	113,800
0.6	6.12.1958	—	—	—	102,320
33.6	21.1.1959	32.3	101.47	185	1,484
Heliocentric orbit		1	450	$146.4 \cdot 10^6$	$197.2 \cdot 10^6$
150 years	—	32.88	125.7	559	3,320
5	5.3.1959	89.7	96	163	968
Heliocentric orbit		0.127	406.9	$147.1 \cdot 10^6$	$173.6 \cdot 10^6$
13	26.4.1959	89.9	90.4	239	346
23 months	July 1961	47.0	765	245	42,400
46	28.9.1959	80.0	94.19	217	739
62	20.10.1959	84.0	95.27	212	848
1.5	14.9.1959	First lunar impact			
300 years	—	33.35	130.0	512	3,744
199	20.4.1960	75	22,300	~ 40,000	~ 480,000
70 years	—	50.31	101.28	556	1,088
19	26.11.1959	81.64	94.7	159	847
108.24	8.3.1960	80.65	103.72	187	1,679
Heliocentric orbit		3.3	312	$120 \cdot 10^6$	$149 \cdot 10^6$
60 years	—	48.4	99.16	693	750
2731	5.10.1967	51.28	95.81	373	748
10.88	26.4.1960	80.1	92.16	170	589
843	5.9.1962	65.0	91.2	312	369
1979	15.10.1965	65.0	94.25	307	690
20 years	—	33.0	94.44	484	511

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
31	USA	Transit-2A	1960η1	22.6.1960	1
		Greb-1	1960η2	22.6.1960	2
32	USA	Discoverer-13	1960θ	10.8.1960	—
33	USA	Echo-1	1960ι1	12.8.1960	4
34	USA	Discoverer-14	1960κ	18.8.1960	—
35	USSR	Second spaceship	1960λ1	19.8.1960	1
36	USA	Discoverer-15	1960μ	13.9.1960	—
37	USA	Courier-1B	1960ν1	4.10.1960	1
38	USA	Explorer-8	1960ξ1	3.11.1960	3
39	USA	Discoverer-17	1960ο	12.11.1960	—
40	USA	Tiros-2	1960π1	23.11.1960	3
41	USSR	Third spaceship	1960ρ1	1.12.1960	1
42	USA	Discoverer-18	1960δ	7.12.1960	—
43	USA	Discoverer-19	1960τ	20.12.1960	—
44	USA	Samos-2	1961α1	31.1.1961	1
45	USSR	Heavy satellite	1961β1	4.2.1961	2
46	USSR	Venyera-1	1961γ1	12.2.1961	1
		Heavy satellite	1961γ3	12.2.1961	—
47	USA	Explorer-9	1961δ1	16.2.1961	4
48	USA	Discoverer-20	1961ε1	17.2.1961	3
49	USA	Discoverer-21	1961ζ	18.2.1961	—
50	USA	Transit-3B — Lofti-1	1961η	22.2.1961	—
51	USSR	Fourth spaceship	1961θ1	9.3.1961	3
52	USSR	Fifth spaceship	1961ι1	25.3.1961	2
53	USA	Explorer-10	1961κ	25.3.1961	—
54	USA	Discoverer-23	1961λ1	8.4.1961	1
		Capsule	1961λ2	8.4.1961	—
55	USSR	Vostok	1961μ1	12.4.1961	1
56	USA	Explorer-11	1961ν	27.4.1961	1
57	USA	Discoverer-25	1961ξ1	16.6.1961	1
58	USA	Transit-4A	1961ο1	29.6.1961	220
		Greb-3 — Injun-1	1961ο2	29.6.1961	—
59	USA	Discoverer-26	1961π	7.7.1961	—
60	USA	Tiros-3	1961ρ1	12.7.1961	3

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
150 years	—	66.69	101.66	628	1,047
80 years	—	66.69	101.66	614	1,061
95.97	14.11.1960	82.85	94.04	258	683
2842	24.5.1968	47.22	118.22	1,524	1,684
28.19	16.9.1960	79.65	94.55	186	805
1	20.8.1960	64.95	90.7	306	339
34.2	18.10.1960	80.90	94.23	199	761
1,000 years	—	28.33	106.85	938	1,237
80 years	—	49.95	112.69	417	2,288
46.6	29.12.1960	81.70	96.45	190	984
60 years	—	48.5	98.20	619	732
1	2.12.1960	64.97	88.47	180	249
116	2.4.1961	81.50	93.66	243	661
33.2	23.1.1961	83.40	93.00	209	631
15 years	—	97.40	94.97	474	557
22	26.2.1961	64.95	89.8	223.5	327.6
Heliocentric orbit		0.5	~ 300	$106 \cdot 10^6$	$151 \cdot 10^6$
13	25.2.1961	65.0	89.6	229	282
1148.2	9.4.1964	38.86	118.28	634	2,583
525.9	28.7.1962	80.91	95.41	288	786
426	20.4.1962	80.74	97.85	240	1,069
36.38	30.3.1961	28.38	96.22	167	1,002
0.08	9.3.1961	64.93	88.6	183.5	248.8
0.08	25.3.1961	64.90	88.42	178.1	247
~ 7 years	June, 1968	33	5,013	221	181,100
373.1	16.4.1962	82.31	94.09	295	651
409.4	23.5.1962	81.94	101.49	208	1,448
0.08	12.4.1961	64.95	89.34	181	327
150 years	—	28.80	107.84	487	1,779
25	12.7.1961	82.11	90.87	222	409
600 years	—	66.81	103.82	881	998
900 years	—	66.82	103.85	882	999
150.4	5.12.1961	82.94	95.02	228	808
100 years	—	47.90	100.33	735	820

Appendix 1

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
61	USA	Midas-3	1961σ1	12.7.1961	3
62	USSR	Vostok-2	1961τ1	6.8.1961	1
63	USA	Explorer-12	1961ν	16.8.1961	—
64	USA	Ranger-1	1961φ1	23.8.1961	1
65	USA	Explorer-13	1961χ	25.8.1961	—
66	USA	Discoverer-29	1961ψ	30.8.1961	—
67	USA	Discoverer-30	1961ω1	12.9.1961	2
68	USA	Mercury-4	1961αα1	13.9.1961	1
69	USA	Discoverer-31	1961αβ	17.9.1961	—
70	USA	Discoverer-32	1961αγ1	13.10.1961	2
71	USA	Midas-4	1961αδ1	21.10.1961	5
72	USA	Discoverer-34	1961αε1	5.11.1961	4
73	USA	Discoverer-35	1961αζ1	15.11.1961	1
74	USA	Transit-4B	1961αη1	15.11.1961	1
		Traac	1961αη2	15.11.1961	—
75	USA	Ranger-2	1961αθ	18.11.1961	—
76	USA	Mercury-5	1961αι1	29.11.1961	1
77	USA	Discoverer-36	1961ακ1	12.12.1961	1
		Oscar-1	1961ακ2	12.12.1961	—
78	USA	US Air Force	1961αλ1	22.12.1961	2
79	USA	Ranger-3	1962α1	26.1.1962	1
80	USA	Tiros-4	1962β1	8.2.1962	3
81	USA	Friendship-7	1962γ1	20.2.1962	1
82	USA	US Air Force	1962δ	21.2.1962	—
83	USA	Discoverer-38	1962ε1	27.2.1962	3
84	USA	OSO-1	1962ζ1	7.3.1962	1
85	USA	US Air Force	1962η1	7.3.1962	2
86	USSR	Cosmos-1	1962θ1	16.3.1962	1
87	USSR	Cosmos-2	1962ι1	6.4.1962	1
88	USA	US Air Force	1962κ1	9.4.1962	3
89	USA	US Air Force	1962λ1	18.4.1962	3
90	USA	Ranger-4	1962μ1	23.4.1962	1
91	USSR	Cosmos-3	1962ν1	24.4.1962	1
92	USSR	Cosmos-4	1962ξ1	26.4.1962	2

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
100,000 years	—	91.2	161.54	3,358	3.534
1.06	7.8.1961	64.93	88.46	183	244
2 years?	—	33.1	1,591	314	77,310
6.89	30.8.1961	32.9	90.64	179	446
2.3	28.8.1961	37.7	97.5	125	1,164
10.2	9.9.1961	82.14	91.51	152	542
90.1	11.12.1961	82.66	92.40	235	546
0.06	13.9.1961	32.8	88.4	156	248
38.57	26.10.1961	82.70	90.86	235	396
30.6	13.11.1961	81.69	90.84	234	395
100,000 years	—	95.89	166.01	3,496	3,756
396.4	7.12.1962	82.52	97.12	227	1,011
17.9	3.12.1961	81.63	89.7	238	278
1,000 years	—	32.43	105.63	956	1,104
800 years	—	32.43	105.64	941	1,119
2	20.11.1961	33.34	88.28	150	242
0.14	29.11.1961	32.6	88.3	158	237
85.3	8.3.1962	81.21	91.82	241	484
49.4	31.1.1962	81.21	91.76	245	474
235	14.8.1962	89.6	94.1	244	702
Heliocentric orbit		0.4	406.44	$147.3 \cdot 10^6$	$173.5 \cdot 10^6$
100 years	—	48.30	100.31	712	840
0.2	20.2.1962	32.54	88.6	159	265
16	9.3.1962	81.97	90.0	167	374
21	21.3.1962	82.23	90.04	208	341
30 years	—	32.85	95.89	556	570
457	7.6.1963	90.89	93.9	251	676
70	25.5.1962	49	96.35	217	980
499	20.8.1963	49	102.25	211.6	1,545.6
100,000 years	—	86.68	153.03	2,814	3,382
40	28.5.1962	73.48	90.9	200	441
2.7	26.4.1962	Lunar impact			
175	17.10.1962	48.98	93.8	229	720
3	29.4.1962	65.0	90.6	298	330

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
93	UK, USA	Ariel-1	1962o1	26.4.1962	1
94	USA	US Air Force	1962π	26.4.1962	—
95	USA	US Air Force	1962ρ1	28.4.1962	1
96	USA	US Air Force	1962σ1	15.5.1962	2
97	USA	Aurora-7	1962τ1	24.5.1962	1
98	USSR	Cosmos-5	1962υ1	28.5.1962	1
99	USA	US Air Force	1962φ1	30.5.1962	1
100	USA	US Air Force	1962χ1	2.6.1962	1
		Oscar-2	1962χ2	2.6.1962	—
101	USA	US Air Force	1962ψ	17.6.1962	—
102	USA	US Air Force	1962ω1	18.6.1962	2
103	USA	Tiros-5	1962αα1	19.6.1962	3
104	USA	US Air Force	1962αβ	23.6.1962	—
105	USA	US Air Force	1962αγ	28.6.1962	—
106	USSR	Cosmos-6	1962αδ1	30.6.1962	1
107	USA	Telstar-1	1962αε1	10.7.1962	1
108	USA	US Air Force	1962αζ1	18.7.1962	1
109	USA	US Air Force	1962αη	21.7.1962	—
110	USA	US Air Force	1962αθ	28.7.1962	—
111	USSR	Cosmos-7	1962αι1	28.7.1962	3
112	USA	US Air Force	1962ακ1	2.8.1962	1
113	USA	US Air Force	1962αλ	5.8.1962	—
114	USSR	Vostok-3	1962αμ1	11.8.1962	1
115	USSR	Vostok-4	1962αν1	12.8.1962	1
116	USSR	Cosmos-8	1962αζ1	18.8.1962	1
117	USA	US Air Force	1962αο1	23.8.1962	3
118		No data	1962απ1	25.8.1962	7
119	USA	Mariner-2	1962αρ1	27.8.1962	1
120	USA	US Air Force	1962ασ	29.8.1962	—
121		No data	1962ατ1	1.9.1962	3
122	USA	US Air Force	1962αν	1.9.1962	—
123		No data	1962αφ	12.9.1962	6
124	USA	US Air Force	1962ακ	17.9.1962	—
125	USA	Tiros-6	1962αψ1	18.9.1962	3

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
20 years	—	53.85	100.86	389	1,214
2	28.4.1962	Orbit unknown			
28	26.5.1962	73.11	91.1	180	475
560	26.11.1963	82.33	94.02	305	634
0.21	24.5.1962	32.5	88.5	154	260
340	2.5.1963	49.07	102.75	203	1,600
12	11.6.1962	74.10	89.7	199	319
26.9	28.6.1962	74.26	90.5	211	385
19	21.6.1962	74.27	90.55	207	394
1	18.6.1962	Orbit unknown			
498.1	30.10.1963	82.14	92.4	370	411
80 years	—	58.08	100.44	588	974
14.7	7.7.1962	75.09	89.58	213	293
78	14.9.1962	76.04	93.6	211	689
70	8.9.1962	49	90.6	274	360
10,000 years	—	44.79	157.65	952	5,632
9	27.7.1962	96.12	88.73	184	236
24	14.8.1962	70.29	90.42	208	381
27	24.8.1962	71.09	90.64	225	386
4	1.8.1962	65	90.1	210	369
24	26.8.1962	82.25	90.77	204	418
1	6.8.1962	96.30	88.62	205	205
3.94	15.8.1962	64.98	88.33	180.7	234.6
2.96	15.8.1962	64.95	88.39	179.8	236.7
364	17.8.1963	49	92.93	256	604
20 years	—	98.6	99.59	620	858
3	28.8.1962	64.88	88.73	173	252
Heliocentric orbit		1.66	345.9	$105.4 \cdot 10^6$	$167.1 \cdot 10^6$
12	10.9.1962	65.21	90.38	187	400
5	6.9.1962	64.9	89.4	180	310
785.5	26.10.1964	82.82	94.42	300	669
2	14.9.1962	64.8	88	176?	176?
62.2	19.11.1962	81.84	93.33	204	668
60 years	—	58.32	98.73	686	713

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
126	USSR	Cosmos-9	1962αω1	27.9.1962	7
127	Canada USA	Alouette-1	1962βα1	29.9.1962	3
128	USA	US Air Force	1962ββ	29.9.1962	—
129	USA	Explorer-14	1962βγ1	2.10.1962	1
130	USA	Sigma-7	1962βδ	3.10.1962	1
131	USA	US Air Force	1962βε	9.10.1962	—
132	USSR	Cosmos-10	1962βζ1	17.10.1962	1
133	USA	Ranger-5	1962βη1	18.10.1962	1
134	USSR	Cosmos-11	1962βθ1	20.10.1962	1
135		No data	1962βι1	24.10.1962	23
136	USA	Star-rad	1962βκ	26.10.1962	—
137	USA	Explorer-15	1962βλ1	27.10.1962	1
138	USA	Anna-1B	1662βμ1	31.10.1962	1
139	USSR	Mars-1	1962βν1	1.11.1962	1
		Heavy satellite	1962βν3	1.11.1962	—
140		No data	1962βξ1	4.11.1962	4
141	USA	US Air Force	1962βο	5.11.1962	—
142	USA	US Air Force	1962βπ	11.11.1962	—
143	USA	US Air Force	1962βρ	24.11.1962	—
144	USA	US Air Force	1962βσ	4.12.1962	—
145	USA	US Air Force	1962βτ1	13.12.1962	4
		Injun-3	1962βτ2	13.12.1962	—
146	USA	Relay-1	1962βϑ1	13.12.1962	1
147	USA	US Air Force	1962βφ	14.12.1962	—
148	USA	Explorer-16	1962βχ	16.12.1962	—
149	USA	Transit-5A	1962βψ1	19.12.1962	3
150	USSR	Cosmos-12	1962βω1	22.12.1962	1
151		No data	1963 01A	4.1.1963	2
152	USA	US Air Force	1963 02A	7.1.1963	1
153	USA	US Air Force	1963 03A	16.1.1963	2
154	USA	Syncom-1	1963 04A	14.2.1963	1
155	USA	US Air Force	1963 05A	19.2.1963	3
156	USSR	Cosmos-13	1963 06A	21.3.1963	1
157	USA	US Air Force	1963 07A	1.4.1963	—

Continued

Life time, days **	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
4	1.10.1962	65	90.9	301	353
2,000 years	—	80.46	105.52	996	1,032
14	14.10.1962	65.40	90.30	203	376
10 years	—	32.95	2,185	281	98,530
0.38	3.10.1962	32.5	88.75	153	285
37.3	16.11.1962	81.96	90.96	213	427
4	21.10.1962	65	90.2	210	380
Heliocentric orbit		0.44	370.22	$142.1 \cdot 10^6$	$159.8 \cdot 10^6$
575	18.5.1964	49	96.1	245	921
5	29.10.1962	64.89	91.18	180?	485?
1805	5.10.1967	71.41	147.87	198	5,570
100 years	—	18.02	315.2	313	17,640
3000 years	—	50.14	107.84	1077	1,182
Heliocentric orbit					
1	2.11.1962	—	—	—	—
1	5.11.1962	64.8	88.75	200?	226?
27	3.12.1962	74.98	90.71	208	409
1	12.11.1962	96.0	88.65	206	206
18	13.12.1962	65.14	89.92	204	337
3	8.12.1962	65.10	89.16	194	273
1519	9.2.1967	70.36	116.26	231	2,786
1515	5.2.1967	70.38	116.32	235	2.785
100,000 years	—	47.49	185.01	1322	7,439
25	8.1.1963	70.97	90.46	199	392
800 years	—	52.01	104.32	750	1,181
60 years	—	90.62	99.12	698	725
8	13.12.1962	65.00	90.45	211	405
1	5.1.1963	64.9	87.5	151?	151?
16.3	24.1.1963	82.23	90.54	205	399
2185	9.1.1969	81.89	94.66	459	533
$> 10^6$ years	—	33.30	1425.5	34.392	36.739
20 years	—	100.48	97.79	505	791
8	29.3.1963	64.97	89.77	205	337
25	26.4.1963	75.40	90.66	201	408

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
158	USSR	Luna-4	1963 08A	2.4.1963	2
159	USA	Explorer-17	1963 09A	3.4.1963	1
160	USSR	Cosmos-14	1963 10A	13.4.1963	1
161	USSR	Cosmos-15	1963 11A	22.4.1963	1
162	USSR	Cosmos-16	1963 12A	28.4.1963	1
163	USA	Telstar-2	1963 13A	7.5.1963	1
164	USA	Midas-6	1963 14A	9.5.1963	85
		TRS-1	1963 14B	9.5.1963	—
		TRS-2	1963 14C	9.5.1963	—
		TRS-3	1963 14D	9.5.1963	—
		Needles	1963 14I	9.5.1963	—
165	USA	Faith-7	1963 15A	15.5.1963	1
166	USA	US Air Force	1963 16A	18.5.1963	—
167	USSR	Cosmos-17	1963 17A	22.5.1963	6
168	USSR	Cosmos-18	1963 18A	24.5.1963	1
169	USA	US Air Force	1963 19A	13.6.1963	—
170	USSR	Vostok-5	1963 20A	14.6.1963	1
171	USA	US Air Force	1963 21A	15.6.1963	2
		Lofti-2	1963 21B	15.6.1963	—
		SR-4	1963 21C	15.6.1963	—
		Radose	1963 21D	15.6.1963	—
		Surcal-1B	1963 21F	15.6.1963	—
172	USA	Transit	1963 22A	16.6.1963	3
173	USSR	Vostok-6	1963 23A	16.6.1963	1
174	USA	Tiros-7	1963 24A	19.6.1963	3
175	USA	US Air Force	1963 25A	27.6.1963	—
		Capsule	1263 25B	27.6.1963	—
176	USA	US Air Force	1963 26A	28.6.1963	—
177	USA	US Air Force	1963 27A	29.6.1963	2
178	USA	US Air Force	1963 28A	12.7.1963	2
179	USA	US Air Force	1963 29A	19.7.1963	1
180	USA	Midas-7	1963 30A	19.7.1963	2
		TRS-4	1963 30B	19.7.1963	—
		US Air Force	1963 30D	19.7.1963	—

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
		Heliocentric orbit			
1331.27	24.11.1966	57.63	96.40	255	917
137	29.8.1963	48.95	92.1	265	512
5	27.4.1963	65	89.77	173	371
10	8.5.1963	65.02	90.4	207	401
200,000 years	—	42.73	225.05	974	10,803
100,000 years	—	87.42	166.48	3,604	3,680
15 years	—	87.35	166.51	3,604	3,683
50,000 years	—	87.42	166.47	3,606	3,678
50,000 years	—	87.41	166.47	3,612	3,672
2—5 years	—	87.35	166.46	3,379	3,915
1.44	16.5.1963	32.54	88.74	161	267
8	27.5.1963	74.54	91.12	153	497
742	2.6.1965	49.03	94.82	260	788
9	2.6.1963	65.02	89.44	209	301
29.1	12.7.1963	81.87	90.67	192	419
4.96	19.6.1963	64.96	88.272	174.7	222.1
53.4	8.8.1963	69.87	95.65	172	919
32.8	18.7.1963	69.87	95.71	171	925
46.7	1.8.1963	69.88	93.00	155	590
44.9	30.7.1963	69.88	94.37	175	837
19.7	5.7.1963	69.86	95.26	169	887
50 years	—	89.97	99.67	724	757
2.95	19.6.1963	64.95	88.3	180.9	231.1
50 years	—	58.23	97.40	621	649
29.7	26.7.1963	81.6	90.5	196	396
60 years	—	82.1	132.55	333	4132
50 years	—	49.74	102.05	411	1311
7 years	—	82.3	94.84	484	536
5.2	18.7.1963	95.37	88.2	164	164
25.8	13.8.1963	82.86	90.44	194	387
100,000 years	—	88.41	168.0	3.670	3,727
5,000 years	—	88.36	168.0	3662	3,734
6 years	—	88.42	168.04	3665	3,745

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
181	USA	Syncom-2	1963 31A	26.7.1963	1
182	USA	US Air Force	1963 32A	31.7.1963	1
183	USSR	Cosmos-19	1963 33A	6.8.1963	1
184	USA	US Air Force	1963 34A	25.8.1963	1
185	USA	US Air Force	1963 35A	29.8.1963	2
		US Air Force	1963 35A	29.8.1963	—
186	USA	US Air Force	1963 36A	6.9.1963	5
187	USA	US Air Force	1963 37B	23.9.1963	—
188	USA	Transit-5B	1963 38B	28.9.1963	4
		SR	1963 38C	28.9.1963	—
189	USA	Vela-Hotel-1	1963 39A	17.10.1963	—
		Vela-Hotel-2	1963 39C	17.10.1963	—
		TRS-5	1963 39B	17.10.1963	—
190	USSR	Cosmos-20	1963 40A	18.10.1963	1
191	USA	US Air Force	1963 41A	25.10.1963	3
192	USA	US Air Force	1963 42A	29.10.1963	1
		US Air Force	1963 42B	29.10.1963	—
193	USSR	Polyot-1	1963 43A	1.11.1963	3
194	USSR	Cosmos-21	1963 44A	11.11.1963	1
195	USSR	Cosmos-22	1963 45A	16.11.1963	1
196	USA	Explorer-18 (IMP-1)	1963 46A	27.11.1963	1
197	USA	Atlas-Centaur-2	1963 47A	27.11.1963	11
198	USA	US Air Force	1963 48A	27.11.1963	—
199	USA	Transit	1963 49B	5.12.1963	—
		US Air Force	1963 49C	5.12.1963	8
200	USSR	Cosmos-23	1963 50A	13.12.1963	3
201	USA	US Air Force	1963 51A	18.12.1963	—
202	USSR	Cosmos-24	1963 52A	19.12.1963	1
203	USA	Fxplorer-19	1963 53A	19.12.1963	9
204	USA	Tiros-8	1963 54A	21.12.1963	3
205	USA	US Air Force	1963 55A	21.12.1963	—
		US Air Force	1963 55B	21.12.1963	—
206	USA	US Air Force	1964 01E	11.1.1964	1
		GGSE-1	1964 01B	11.1.1964	—

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
$> 10^6$ years	—	33.05	1454.0	35,584	35,693
12	12.8.1963	74.95	90.4	157	411
237	30.3.1964	49	92.2	270	519
18.6	12.9.1963	75.01	89.4	161	320
69.7	7.11.1963	81.89	90.80	292	324
24-30	23-29.9.1963	81.89	92.07	310	431
7.05	13.9.1963	94.37	89.06	168	263
18.2	12.10.1963	74.90	90.63	161	441
1,000 years	—	89.90	107.42	1,075	1,127
1,000 years	—	89.89	107.40	1,075	1,126
$> 10^6$ years	—	38.3	6270	100,122	118,122
$> 10^6$ years	—	37.8	6370	110,122	118,122
1 years	—	36.77	2329	220	103,500
12	30.10.1963	65	89.55	206	311
4	29.10.1963	99.05	88.99	144	332
83.51	21.1.1964	89.90	90.84	279	345
571	23.5.1965	89.99	93.35	285	585
25 years	—	58.92	102.5	339	1,437
3	15.11.1963	64.83	88.5	195	229
6	22.11.1963	64.93	90.3	205	394
2 years?	—	33.34	5,666	192	197,616
500 years	—	30.34	107.46	544	1,699
17.3	15.12.1963	69.99	90.2	175	386
1,000 years	—	89.98	107.18	1,067	1,112
1,000 years	—	89.95	107.16	1,069	1,111
104	27.3.1963	40	92.9	240	613
1.28	20.12.1963	97.89	88.48	122	266
9	28.12.1963	65	90.5	211	408
10 years	—	78.62	115.93	590	2,394
60 years	—	58.48	99.33	691	765
18	8.1.1964	64.94	89.96	176	355
326.89	7.11.1964	64.52	91.68	321	388
1,000 years	—	69.90	103.48	905	934
1,000 years	—	69.94	103.47	898	942

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
206	USA	Secor-1 (EGRS-1)	1964 01C	11.1.1964	—
		SR-5 (Greb-5)	1964 01D	11.1.1964	—
207	USA	US Air Force	1964 02C	19.1.1964	1
		Capsule	1964 02B	19.1.1964	—
208	USA	Relay-2	1964 03A	21.1.1964	1
209	USA	Echo-2	1964 04A	25.1.1964	4
210	USA	Saturn SA-5	1964 05A	29.1.1964	—
211	USSR	Electron-1	1964 06A	30.1.1964	2
		Electron-2	1964 06B	30.1.1964	—
212	USA	Ranger-6	1964 07A	30.1.1964	1
213	USA	US Air Force	1964 08A	15.2.1964	1
214	USA	US Air Force	1964 09A	25.2.1964	1
215	USSR	Cosmos-25	1964 10A	27.2.1964	3
216	USA	US Air Force	1964 11A	28.2.1964	3
217	USA	US Air Force	1964 12A	11.3.1964	1
218	USSR	Cosmos-26	1964 13A	18.3.1964	3
219	USSR	Cosmos-27	1964 14A	27.3.1964	3
220	UK, USA	Ariel-2	1964 15A	27.3.1964	2
221	USSR	Zond-1	1964 16D	2.4.1964	—
		Heavy satellite	1964 16A	2.4.1964	2
222	USSR	Cosmos-28	1964 17A	4.4.1964	2
223	USA	Gemini-1	1964 18A	8.4.1964	—
224	USSR	Polyot-2	1964 19B	12.4.1964	1
225	USA	US Air Force	1964 20A	23.4.1964	4
226	USSR	Cosmos-29	1964 21A	25.4.1964	4
227	USA	US Air Force	1964 22A	27.4.1964	—
228	USSR	Cosmos-30	1964 23A	18.5.1964	1
229	USA	US Air Force	1964 24A	19.5.1964	—
230	USA	Saturn SA-6 (Apollo-1)	1964 25A	28.5.1964	—
231	USA	Transit	1964 26A	4.6.1964	4
232	USA	US Air Force	1964 27A	4.6.1964	—
233	USSR	Cosmos-31	1964 28A	6.6.1964	1
234	USSR	Cosmos-32	1964 29A	10.6.1964	2

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
1,500 years	—	69.89	103.46	904	933
1,000 years	—	69.90	103.47	905	934
300 years	—	99.07	101.32	811	825
300 years	—	99.04	101.31	801	830
$> 10^6$ years	—	46.32	194.60	2,091	7,411
15 years	—	81.50	108.95	1,029	1,316
821.4	30.4.1966	31.43	94.41	264	756
200 years	—	61	169	406	7,100
30 years	—	61	1,360	460	68,200
2.7	2.2.1964	Lunar impact			
23	9.3.1964	74.95	90.86	179	444
4	1.3.1964	95.66	88.24	173	190
267	21.11.1964	49	92.27	272	526
7 years	—	82.03	94.74	479	520
4.3	16.3.1964	95.73	88.2	163	203
194	28.9.1964	49	91	271	403
1	28.3.1964	64.80	88.7	192	237
1,331	18.11.1967	51.64	101.29	285	1,362
Heliocentric orbit		~ 4	~ 290	$\sim 97 \cdot 10^6$	$\sim 158 \cdot 10^6$
1	3.4.1964	Orbit unknown			
8	12.4.1964	65	90.38	209	395
4.2	12.4.1964	32.56	89.00	154	299
787	8.6.1966	58.06	92.4	310	500
5.2	29.4.1964	103.56	89.40	150	336
7	2.5.1964	65.07	89.52	204	309
28.19	26.5.1964	79.93	90.77	178	446
8	26.5.1964	64.93	90.24	206.6	383.1
2.9	22.5.1964	101.12	89.69	141	380
3.31	1.6.1964	31.74	88.22	179	204
200 years	—	90.42	103.12	854	956
13.94	18.6.1964	79.96	90.27	149	429
136	20.10.1964	49	91.6	228	508
8	18.6.1964	51.28	89.78	209	333

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
235	USA	Starflash-1A	1964 30A	13.6.1964	1
236	USA	US Air Force	1964 31A	18.6.1964	1
		Capsule	1964 31B	18.6.1964	—
237	USA	US Air Force	1964 32A	19.6.1964	1
238	USSR	Cosmos-33	1964 33A	23.6.1964	3
239	USSR	Cosmos-34	1964 34A	1.7.1964	1
240	USA	US Air Force	1964 35A	3.7.1964	—
241	USA	US Air Force	1964 36A	6.7.1964	2
242	USA	US Air Force	1964 37A	10.7.1964	—
243	USSR	Electron-3	1964 38A	11.7.1964	2
		Electron-4	1964 38B	11.7.1964	—
244	USSR	Cosmos-35	1964 39A	15.7.1964	3
245	USA	Vela-Hotel-3	1964 40A	17.7.1964	1
		Vela-Hotel-4	1964 40B	17.7.1964	—
		TRS-6	1964 40C	17.7.1964	—
246	USSR	Ranger-7	1964 41A	28.7.1964	1
247	USSR	Cosmos-36	1964 42A	30.7.1964	1
248	USA	US Air Force	1964 43A	5.8.1964	—
249	USSR	Cosmos-37	1964 44A	14.8.1964	1
250	USA	US Air Force	1964 45A	14.8.1964	1
		Capsule	1964 45B	14.8.1964	—
251	USSR	Cosmos-38	1964 46A	18.8.1964	4
		Cosmos-39	1964 46B	18.8.1964	—
		Cosmos-40	1964 46C	18.8.1964	—
252	USA	Suncom-3	1964 47A	19.8.1964	1
253	USA	Starflash-1B	1964 48A	21.8.1964	—
254	USSR	Cosmos-41	1964 49D	22.8.1964	4
255	USSR	Cosmos-42	1964 50A	22.8.1964	1
		Cosmos-43	1964 50C	22.8.1964	—
256	USA	Explorer-20	1964 51A	25.8.1964	4
257	USA	Nimbus-1	1964 52A	28.8.1964	1
258	USA	Cosmos-44	1964 53A	28.8.1964	1
259	USA	OGO-1	1964 54A	5.9.1964	1
260	USSR	Cosmos-45	1964 55A	13.9.1964	1

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
354.21	2.6.1965	114.98	91.67	350	364
500 years	—	99.84	101.64	828	842
500 years	—	99.83	101.64	828	842
26.81	16.7.1964	85.0	90.95	176	462
8	1.7.1964	65	89.38	209	293
8	9.7.1964	64.97	90.0	205	360
7 years	—	82.09	94.94	501	529
2	8.7.1964	92.89	89.20	121	346
26.52	6.8.1964	84.98	91.0	180	461
200 years	—	60.87	168	405	7,040
23 years	—	60.87	1,314	459	66,235
8	23.7.1964	51.3	89.2	217	268
10^6 years	—	39.58	6022.6	101,959	104,591
10^6 years	—	40.88	6007.0	94,436	111,775
18 months?	—	36.7	2,364	220	105,000
2.83	31.7.1964		Lunar impact		
212	28.2.1965	49	91.9	259	503
26	1.9.1964	79.96	90.71	182	436
8	22.8.1964	65.0	89.45	205	300
8.8	23.8.1964	95.52	89.0	149	307
30 years	—	95.67	127.40	275	3,748
82	8.11.1964	56.17	95.2	210	876
91	17.11.1964	56.17	95.2	210	876
92	18.11.1964	56.17	95.2	210	876
$> 10^6$ years	—	0.10	1407.8	34,191	36,271
221.66	31.3.1965	115.0	9,160	349	363
46 years	—	64.0	715.0	394	39,855
484	19.12.1965	49.0	97.8	232	1,099
492	27.12.1965	49.0	97.8	232	1,099
800 years	—	79.77	104.09	878	1,024
15 years	—	98.66	98.42	429	937
100 years	—	65	99.5	618	860
16 years	—	31.15	3838.8	281	149,385
5	18.9.1964	64.90	8,969	206	327

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
261	USA	US Air Force	1964 56A	14.9.1964	1
262	USA	Saturn-SA7 (Apollo-2)	1964 57A	18.9.1964	1
263	USA	US Air Force	1964 58A	23.9.1964	1
264	USSR	Cosmos-46	1964 59A	24.9.1964	1
265	USA	Explorer-21 (IMP-2)	1964 60A	4.10.1964	1
266	USA	US Air Force	1964 61A	5.10.1964	—
267	USSR	Cosmos-47	1964 62A	6.10.1964	4
268	USA	US Air Force	1964 63B	6.10.1964	3
		US Air Force	1964 63C	6.10.1964	—
		US Air Force	1964 63E	6.10.1964	—
269	USA	Explorer-22	1964 64A	10.10.1964	3
270	USSR	Voskhod	1964 65A	12.10.1964	2
271	USSR	Cosmos-48	1964 66A	14.10.1964	2
272	USA	US Air Force	1964 67A	17.10.1964	—
273	USA	US Air Force	1964 68A	23.10.1964	2
		Capsule	1964 68B	23.10.1964	—
274	USSR	Cosmos-49	1964 69A	24.10.1964	2
275	USSR	Cosmos-40	1964 70A	28.10.1964	104
276	USA	US Air Force	1964 71A	2.11.1964	—
277	USA	US Air Force	1964 72A	4.11.1964	3
278	USA	Mariner-3	1964 73A	5.11.1964	1
279	USA	Explorer-23	1964 74A	6.11.1964	1
280	USA	US Air Force	1964 75A	18.11.1964	—
281	USA	Explorer-24	1964 76A	21.11.1964	11
		Explorer-25 (Injun-4)	1964 76B	21.11.1964	—
282	USA	Mariner-4	1964 77A	28.11.1964	1
283	USSR	Zond-2	1964 78C	30.11.1964	1
		Heavy satellite	1954 78A	30.11.1964	—
284	USA	US Air Force	1964 79A	4.12.1964	—
285	USSR	Cosmos-52	1964 80A	10.12.1964	5
286	USA	Transtage-2 (Titan-3A)	1964 81A	10.12.1964	—
287	USA	Atlas—Centaur-4	1964 82A	11.12.1964	—
288	USA	SR	1964 83C	13.12.1964	—

Continued

Life time days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
21.7	6.10.1964	84.96	90.88	238	466
3.86	22.9.1964	31.72	88.30	178	203
4.78	28.9.1964	92.91	89.00	145	303
8	2.10.1964	51.30	89.2	215	271
15 months	Jan., 1966	33.53	2,097	190	95,595
20.5	26.10.1964	79.97	90.75	182	440
1	7.10.1964	64.77	90	177	413
1,000 years	—	89.92	106.65	1,055	1,085
200 years	—	89.93	106.63	1,054	1,084
2,000 years	—	89.97	106.66	1,056	1,086
2,000 years	—	79.69	104.70	885	1,077
1.01	13.10.1964	64.82	90.087	177.5	408
6	20.10.1964	65.07	89.4	203	295
17.28	14.11.1964	74.99	90.59	189	416
5.07	28.10.1964	95.55	88.6	139	271
123.23	23.2.1965	95.50	91.14	323	336
301	21.8.1965	49	91.83	260	490
8	5.11.1964	51.30	88.7	196	241
25.34	28.11.1964	79.95	90.70	180	448
7 years	—	82.00	95.05	512	526
Heliocentric orbit		0.15	448	$147 \cdot 10^6$	$196 \cdot 10^6$
50 years	—	51.95	99.17	466	977
17.41	6.12.1964	70.02	89.71	180	339
1427	18.10.1968	81.36	116.30	525	2,498
200 years	—	81.36	116.27	522	2,494
Heliocentric orbit		0.15	486	$148 \cdot 10^6$	$214 \cdot 10^6$
Heliocentric orbit					
1	1.12.1964	64.72	88.16	153	219
1.2	6.12.1964	97.02	89.69	158	357
339.9	14.11.1965	48.8	92.5	264	554
2.95	13.12.1964	32.15	87.60	157	170
0.63	12.12.1964	30.71	87.81	165	178
1,000 years	—	89.99	106.36	1,027	1,086

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
288	USA	Transit	1964 83D	13.12.1964	9
289	Italy, USA	San-Marco-1	1964 84A	15.12.1964	2
290	USA	US Air Force	1964 85A	19.12.1964	—
291	USA	Explorer-26	1964 86A	21.12.1964	1
292	USA	US Air Force	1964 87A	21.12.1964	—
293	USSR	Cosmos-52	1965 01A	11.1.1965	3
294	USA	US Air Force	1965 02A	15.1.1965	1
295	USA	US Air Force	1965 03A	19.1.1965	2
296	USA	Tiros-9	1965 04A	22.1.1965	3
297	USA	US Air Force	1965 05A	23.1.1965	1
298	USSR	Cosmos-53	1965 06A	30.1.1965	3
299	USA	OSO-2	1965 07A	3.2.1965	1
300	USA	Transtage-3 (Titan-3A)	1965 08A	11.2.1965	1
		LES-1	1965 08C	11.2.1965	—
301	USA	Pegasus-1	1965 09A	16.2.1965	—
		Apollo-3	1965 09B	16.2.1965	—
302	USA	Ranger-8	1965 10A	17.2.1965	1
303	USSR	Cosmos-54	1965 11A	21.2.1965	2
		Cosmos-55	1965 11B	21.2.1965	—
		Cosmos-56	1965 11C	21.2.1965	—
304	USSR	Cosmos-57	1965 12A	22.2.1965	183
305	USA	US Air Force	1965 13A	25.2.1965	1
306	USSR	Cosmos-58	1965 14A	26.2.1965	1
307	USSR	Cosmos-59	1965 15A	7.3.1965	2
308	USA	SR-6 (Greb)	1965 16A	9.3.1965	1
		GGSE-2	1965 16B	9.3.1965	—
		GGSE-3	1965 16C	9.3.1965	—
		SR-7 (Greb)	1965 16D	9.3.1965	—
		Secor-3 (EGRS-3)	1965 16E	9.3.1965	—
		Oscar-3	1965 16F	9.3.1965	—
		Surcal-2	1965 16G	9.3.1965	—
		Dodecapol-1	1965 16H	9.3.1965	—

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
1,000 years	—	89.86	106.33	1,025	1,084
270.12	11.9.1965	37.77	94.94	198	846
26	14.1.1965	74.97	90.46	183	410
30 years	—	20.14	456.26	316	26,191
21.6	11.1.1965	70.08	89.5	238	264
8	19.1.1965	65	89.5	205	304
25	9.2.1965	74.95	90.52	180	420
20 years	—	98.78	97.68	471	822
1,000 years	—	96.41	119.23	705	2,582
5	29.1.1965	102.5	88.85	146	291
559	12.8.1966	48.8	98.7	227	1,192
40 years	—	32.87	96.40	550	634
50,000 years	—	32.15	145.47	2,776	2,802
50,000 years	—	32.1	145.4	2,782	2,789
20 years	—	31.73	96.80	495	733
20 years	—	31.76	96.90	498	736
2.71	20.2.1965	Lunar impact			
1,303	16.9.1968	56.07	106.2	279.7	1,856
1,076	3.2.1968	56.07	106.2	279.7	1,856
985	3.11.1967	56.07	106.2	279.7	1,856
0.1	22.2.1965	64.77	91.1	175	512
20	17.3.1965	75.08	90.07	177	377
50 years	—	65.0	96.8	581	659
8	15.3.1965	65.0	89.7	209	339
1,000 years	—	70.09	103.52	910	939
1,000 years	—	70.11	103.50	902	946
1,000 years	—	70.09	103.52	910	939
1,000 years	—	70.09	103.52	910	939
1,000 years	—	70.08	103.51	909	938
1,000 years	—	70.12	103.50	902	946
1,000 years	—	70.06	103.50	901	945
1,000 years	—	70.08	103.51	910	939

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
309	USA	Capsule	1965 17A	11.3.1965	5
		Secor-2 (EGRS-2)	1965 17B	11.3.1965	—
		US Air Force	1965 17D	11.3.1965	—
310	USSR	Cosmos-60	1965 18A	12.3.1965	2
311	USA	US Air Force	1965 19A	12.3.1965	2
312	USSR	Cosmos-61	1965 20A	15.3.1965	148
		Cosmos-62	1965 20B	15.3.1965	—
		Cosmos-63	1965 20C	15.3.1965	—
313	USA	US Air Force	1965 21A	18.3.1965	5
314	USSR	Voskhod-2	1965 22A	18.3.1965	3
315	USA	Ranger-9	1965 23A	21.3.1965	1
316	USA	Gemini-3	1965 24A	23.3.1965	1
317	USSR	Cosmos-64	1965 25A	25.3.1965	2
318	USA	US Air Force	1965 26A	25.3.1965	1
319	USA	SNAP-10A	1965 27A	3.4.1965	3
		Secor-4 (EGRS-4)	1965 27B	3.4.1965	—
320	USA	Early Bird	1965 28A	6.4.1965	1
321	USSR	Cosmos-65	1965 29A	17.4.1965	2
322	USSR	Molniya-1	1965 30A	23.4.1965	3
323	USA	US Air Force	1965 31A	28.4.1965	5
		Capsule	1965 31B	28.4.1965	—
324	USA	Explorer-27	1965 32A	29.4.1965	3
325	USA	US Air Force	1965 33A	29.4.1965	—
		Capsule	1965 33B	29.4.1965	—
326	USA	Transtage-4 (Titan-3A)	1965 34A	6.5.1965	1
		LES-2	1965 34B	6.5.1965	—
		Surcal	1965 34C	6.5.1965	—
327	USSR	Cosmos-66	1965 35A	7.5.1965	3
328	USSR	Luna-5	1965 36A	9.5.1965	1
		Heavy satellite	1965 36B	9.5.1965	—
329	USA	US Air Force	1965 37A	18.5.1965	1
330	USA	US Air Force	1965 38A	20.5.1965	6
331	USA	Pegasus-2	1965 39A	25.5.1965	—

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Pericd, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
94.72	14.6.1965	89.97	95.19	211	890
1082	26.2.1968	89.98	97.85	296	1,014
870	29.7.1967	89.99	97.97	289	1,035
5	17.3.1965	64.7	89.1	201	287
4.98	17.3.1965	107.69	88.51	155	247
1036	15.1.1968	56	106	273	1,837
1289	25.9.1968	56	106	273	1,837
964	4.11.1967	56	106	273	1,837
25 years	—	99.12	97.68	525	764
1.09	19.3.1965	64.79	90.944	173.5	497.7
2.69	24.3.1965		Lunar impact		
0.2	23.3.1965	33	88.37	160	240
8	2.4.1965	65	89.2	206	271
10.1	5.4.1965	96.08	89.06	186	265
5,000 years	—	89.97	111.58	1,282	1,313
5,000 years	—	90.03	111.58	1,282	1,313
$>10^6$ years	—	0.14	1436.4	34,995	36,564
8	25.4.1965	65	89.8	210	342
14 years	—	65	720	548	39,957
5.14	3.5.1965	95.60	88.95	180	259
7 years	—	95.26	95.16	490	559
3,000 years	—	41.19	107.78	941	1,317
26.5	26.5.1965	85.04	91.05	178	473
39.43	8.6.1965	84.85	98.12	197	1,141
50,000 years	—	32.06	156.93	2,782	3,746
10^6 years	—	31.36	315.16	2,828	15,102
30,000 years	—	32.11	145.42	2,704	2,869
8	15.5.1965	65	89.3	197	291
~ 3.5	12.5.1965		Lunar impact		
1	10.5.1965	64.78	88.25	151	217
28.24	15.6.1965	75.01	89.71	198	331
30 years	—	98.69	100.06	567	953
20 years	—	31.73	96.99	502	740

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
331	USA	Apollo-4	1965 39B	25.5.1965	—
332	USSR	Cosmos-67	1965 40A	25.5.1965	3
333	USA	US Air Force	1965 41A	27.5.1965	—
334	USA	Explorer-28 (IMP-3)	1965 42A	29.5.1965	1
335	USA	Gemini-4	1965 43A	3.6.1965	1
336	USSR	Luna-6	1965 44A	8.6.1965	1
		Heavy satellite	1965 44B	8.6.1965	—
337	USA	US Air Force	1965 45A	9.6.1965	1
338	USSR	Cosmos-68	1965 46A	15.6.1965	4
339	USA	Transtage-5 (Titan-3C)	1965 47B	18.6.1965	1
340	USA	US Air Force	1965 48A	24.6.1965	3
		US Air Force	1965 48B	24.6.1965	—
341	USSR	Cosmos-69	1965 49A	25.6.1965	2
342	USA	Capsule	1965 50A	25.6.1965	3
		US Air Force	1965 50B	25.6.1965	—
343	USA	Tiros-10	1965 51A	2.7.1965	3
344	USSR	Cosmos-70	1965 52A	2.7.1965	2
345	USSR	Cosmos-71	1965 53A	16.7.1965	5
		Cosmos-72	1965 53B	16.7.1965	—
		Cosmos-73	1965 53C	16.7.1965	—
		Cosmos-74	1965 53D	16.7.1965	—
		Cosmos-75	1965 53E	16.7.1965	—
346	USSR	Proton-1	1965 54A	16.7.1965	3
347	USA	US Air Force	1965 55A	17.7.1965	4
348	USSR	Zond-3	1965 56A	18.7.1965	1
		Heavy satellite	1965 56B	18.7.1965	—
349	USA	US Air Force	1965 57A	19.7.1965	—
350	USA	Vela-Hotel-5	1965 58A	20.7.1965	1
		Vela-Hotel-6	1965 58B	20.7.1965	—
		ORS-3 (ERS-17)	1965 58C	20.7.1965	—
351	USSR	Cosmos-76	1965 59A	23.7.1965	1
352	USA	Pegasus-3	1965 60A	30.7.1965	—
		Appolo-5	1965 60B	30.7.1965	—

Spacecraft launched	Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
Continued						
	20 years	—	31.74	97.04	512	736
	8	2.6.1965	51.8	89.9	207	350
	4	1.6.1965	95.78	88.67	149	267
	3 years	—	34.0	8,550	190	264,000
	4.07	7.6.1965	32.53	88.82	162	281
			Heliocentric orbit			
	4	12.6.1965	64.76	88.65	167	246
	12.58	22.6.1965	75.07	89.84	176	362
	8	23.6.1965	65	89.77	205	334
	3.30	21.6.1965	32.13	87.75	163	176
	1,000 years	—	90.00	106.92	1,024	1,144
	1,000 years	—	90.00	106.94	1.025	1,144
	8	3.7.1965	65	89.7	211	332
	1153	22.8.1968	107.65	94.68	496	510
	4.9	30.6.1965	107.64	88.78	151	283
	80 years	—	98.65	100.76	751	837
	534	18.12.1966	48.8	98.43	229	1,154
	10 years	—	56.1	95.5	550	550
	25 years	—	56.1	95.5	550	550
	20 years	—	56.1	95.5	550	550
	25 years	—	56.1	95.5	550	550
	25 years	—	56.1	95.5	550	550
	87	11.10.1965	63.5	92.45	190	627
	1250	18.12.1968	70.18	94.46	471	512
			Heliocentric orbit			
	2	20.7.1965	64.78	88.18	164	210
	29	18.8.1965	85.05	91.01	182	464
	$> 10^6$ years	—	35.27	5148.16	88,534	96,238
	$> 10^6$ years	—	34.99	6726.4	101,859	121,453
	10 years?	—	34.39	2608.81	153	112,694
	236	16.3.1966	48.8	92.2	261	530
	10 years	—	28.80	95.52	535	567
	10 years	—	28.86	95.02	519	534

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
353	USSR	Cosmos-77	1965 61A	3.8.1965	1
354	USA	US Air Force	1965 62A	3.8.1965	1
		Capsule	1965 62B	3.8.1965	—
355	USA	Secor-5 (EGRS-5)	1965 63B	10.8.1965	1
356	USA	Surveyor (Model-1)	1965 64A	11.8.1965	1
357	USA	Surcal	1965 65A	13.8.1965	9
		Dodecapol-2	1965 65C	13.8.1965	—
		US Air Force	1965 65E	13.8.1965	—
		Transit	1965 65F	13.8.1965	—
		Surcal	1965 65H	13.8.1965	—
		Surcal	1965 65K	13.8.1965	—
358	USSR	Cosmos-78	1965 66A	14.8.1965	2
359	USA	US Air Force	1965 67A	17.8.1965	—
360	USA	Gemini-5	1965 68A	21.8.1965	3
361	USSR	Cosmos-79	1965 69A	25.8.1965	4
362	USSR	Cosmos-80	1965 70A	3.9.1965	2
		Cosmos-81	1965 70B	3.9.1965	—
		Cosmos-82	1965 70C	3.9.1965	—
		Cosmos-83	1965 70D	3.9.1965	—
		Cosmos-84	1965 70E	3.9.1965	—
363	USSR	Cosmos-85	1965 71A	9.9.1965	1
364	USA	US Air Force	1965 72A	10.9.1965	5
365	USSR	Cosmos-86	1965 73A	18.9.1965	7
		Cosmos-87	1965 73B	18.9.1965	—
		Cosmos-88	1965 73C	18.9.1965	6
		Cosmos-89	1965 73D	18.9.1965	—
		Cosmos-90	1965 73E	18.9.1965	—
366	USA	US Air Force	1965 74A	22.9.1965	—
367	USSR	Cosmos-91	1965 75A	23.9.1965	4
368	USA	US Air Force	1965 76B	30.9.1965	—
		Capsule	1965 76A	30.9.1965	—
369	USSR	Luna-7	1965 77A	4.10.1965	2
		Heavy satellite	1965 77B	4.10.1965	—
370	USA	OV-1-2	1965 78A	5.10.1965	1

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Haight of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
8	11.8.1965	51.84	89.3	200	291
4.11	7.8.1965	107.47	89,06	149	307
7 years	—	107.36	94.78	501	515
10,000 years	—	69.26	122.24	1,140	2,423
		Heliocentric orbit			
1,000 years	—	90.02	108.19	1,074	1,209
1,000 years	—	90.03	108.14	1,094	1,184
1,000 years	—	90.03	108.17	1,096	1,186
1,000 years	—	90.01	108.19	1,089	1,194
200 years	—	90.05	108.19	1,082	1,201
1,000 years	—	90.02	108.14	1,094	1,184
8	22.8.1965	69	89.8	206	329
54.4	11.10.1965	70.04	90.37	180	407
7.96	29.8.1965	32.61	89.38	197	303
8	2.9.1965	64.9	90	211	359
10,000 years	—	66	116.6	1,500	1,500
10,000 years	—	56	116.6	1,500	1,500
10,000 years	—	56	116.6	1,500	1,500
10,000 years	—	56	116.6	1,500	1,500
10,000 years	—	56	116.6	1,500	1,500
8	17.9.1965	65	89.6	212	319
50 years	—	98.65	101.93	649	1,054
10,000 years	—	56	116.7	1,380	1,690
10,000 years	—	56	116.7	1,380	1,690
10,000 years	17.9.1965	56	116.7	1,380	1,690
10,000 years	—	56	116.7	1,380	1,690
10,000 years	—	56	116.7	1,380	1,690
18	11.10.1965	80.01	90.04	191	364
8	1.10.1965	65	89.8	212	342
2	3.10.1965	95.60	88.77	158	264
4.7	5.10.1965	95.60	88.77	158	264
~3.5	7.10.1965		Lunar impact		
0.6	4.10.1965	64.75	88.62	129	286
100 years	—	144.30	125.58	403	3,462

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
371	USA	US Air Force	1965 79A	5.10.1965	—
372	USSR	Molniya-1	1965 80A	14.10.1965	3
373	USA	OGO-2	1965 81A	14.10.1965	1
374	USA	Transtage-6 (Titan-3C)	1965 82A	15.10.1965	490
375	USSR	Cosmos-92	1965 83A	16.10.1965	2
376	USSR	Cosmos-93	1965 84A	19.10.1965	4
377	USSR	Cosmos-94	1965 85A	28.10.1965	1
378	USA	US Air Force	1965 86A	28.10.1965	1
379	USSR	Proton-2	1965 87A	2.11.1965	4
380	USSR	Cosmos-95	1965 88A	4.11.1965	25
381	USA	Explorer-29 (HEOS-21)	1965 89A	6.11.1965	2
382	USA	US Air Force	1965 90A	8.11.1965	1
383	USSR	Venyera-2	1965 91A	12.11.1965	2
384	USSR	Venyera-3	1965 92A	16.11.1965	4
385	USR	Explorer-30 (IQSY)	1965 93A	19.11.1965	3
386	USSR	Cosmos-96	1965 94A	23.11.1965	7
387	USSR	Cosmos-97	1965 95A	26.11.1965	3
388	France	Asterix-1	1965 96A	26.11.1965	2
389	USSR	Cosmos-98	1965 97A	27.11.1965	2
390	Canada, USA	Alouette-2	1965 98A	29.11.1965	8
		Explorer-31 (DME-A)	1965 98B	29.11.1965	—
391	USSR	Luna-8	1965 99A	3.12.1965	2
		Heavy satellite	1965 99B	3.12.1965	—
392	USA	Gemini-7	1965 100A	4.12.1965	2
393	France, USA	FR-1	1965 101A	6.12.1965	3
394	USA	US Air Force	1965 102A	9.12.1965	1
395	USSR	Cosmos-99	1965 103A	10.12.1965	1
396	USA	Gemini-6	1965 104A	15.12.1965	1
397	USA	Pioneer-6	1965 105A	16.12.1965	1
398	USSR	Cosmos-100	1965 106A	17.12.1965	1
399	USSR	Cosmos-101	1965 107A	21.12.1965	1
400	USA	LES-3	1965 108D	21.12.1965	—

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
24	29.10.1965	75.05	89.75	203	323
518	17.3.1967	65	719	500	40,000
50 years	—	87.43	104.41	415	1,517
100 years	—	32.61	99.70	706	792
8	24.10.1965	65	89.9	212	353
76	3.1.1966	48.40	91.7	220	522
8	5.11.1965	65	89.3	211	293
19.81	17.11.1965	74.97	90.54	176	430
96	6.2.1966	63.50	92.6	191	637
75	18.1.1966	48.4	91.7	207	521
50,000 years	—	59.38	120.30	1,115	2,277
2.9	11.11.1965	93.88	88.74	145	277
		Heliocentric orbit			
105	1.3.1966		Lunar impact		
200 years	—	59.72	100.80	704	891
16	9.12.1965	51.9	89.6	227	310
492	2.4.1967	49	108.3	220	2,100
200 years	—	34.24	108.61	527	1,808
8	5.12.1965	65	92	216	570
500 years	—	79.82	121.43	505	2,987
500 years	—	79.82	121.39	505	2,978
3.5	6.12.1965		Lunar impact		
1.63	5.12.1965	51.82	88.20	169	209
13.78	18.12.1965	28.87	89.75	215	321
60 years	—	75.87	99.94	746	762
16.78	26.12.1965	80.04	90.72	183	437
8	18.12.1965	65	89.6	199	320
1.08	16.12.1965	28.89	89.64	258	271
	Heliocentric orbit		311	$121.8 \cdot 10^6$	
80 years	—	65	97.7	~650	~650
203	12.7.1966	49	92.4	260	550
836	6.4.1968	26.46	581.41	195	33,177

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
400	USA	Transtage-7	1965 108A	21.12.1965	—
		LES-4	1965 108B	21.12.1965	—
		Oscar-4	1965 108C	21.12.1965	—
401	USA	US Air Force	1965 109A	22.12.1965	4
402	USA	US Air Force	1965 110A	24.12.1965	1
403	USSR	Cosmos-102	1965 111A	28.12.1965	—
404	USSR	Cosmos-103	1965 112A	28.12.1965	16
405	USSR	Cosmos-104	1966 01A	7.1.1966	2
406	USA	Capsule	1966 02A	19.1.1966	—
		US Air Force	1966 02B	19.1.1966	—
407	USSR	Cosmos-105	1966 03A	22.1.1966	2
408	USSR	Cosmos-106	1966 04A	25.1.1966	1
409	USA	US Air Force	1966 05A	28.1.1966	5
410	USSR	Luna-9	1966 06A	31.1.1966	1
		Heavy satellite	1966 06B	31.1.1966	—
411	USA	US Air Force	1966 07A	2.2.1966	—
412	USA	ESSA-1	1966 08A	3.2.1966	4
413	USA	US Air Force	1966 09A	9.2.1966	2
414	USSR	Cosmos-107	1966 10A	10.2.1966	3
415	USSR	Cosmos-108	1966 11A	11.2.1966	2
416	USA	US Air Force	1966 12A	15.2.1966	43
417	France	Diaposone-1	1966 13A	17.2.1966	7
418	USSR	Cosmos-109	1966 14A	19.2.1966	2
419	USSR	Cosmos-110	1966 15A	22.2.1966	3
420	USA	ESSA-2	1966 16A	28.2.1966	3
421	USSR	Cosmos-111	1966 17A	1.3.1966	2
422	USA	US Air Force	1966 18A	9.3.1966	1
423	USA	Agena-8	1966 19A	16.3.1966	—
424	USA	Gemini-8	1966 20A	16.3.1966	2
425	USSR	Cosmos-112	1966 21A	17.3.1966	2
426	USA	US Air Force	1966 22B	18.3.1966	1
427	USSR	Cosmos-113	1966 23A	21.3.1966	2
428	USA	US Air Force	1966 24A	26.3.1966	2
429	USA	OV-1-4	1966 25A	30.3.1966	1

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
5 years	—	26.38	589.26	167	33,662
10 years	—	26.60	589.24	189	33,632
10 years	—	26.80	587.49	162	33,561
1,000 years	—	89.11	105.09	909	1,086
26.59	20.1.1966	80.01	90.83	178	446
17	14.1.1966	65	89.24	218	278
60 years	—	56	97	~600	600
8	15.1.1966	65	90.2	204	401
6	25.1.1966	93.86	88.72	150	269
3.88	23.1.1966	93.89	88.51	154	246
8	30.1.1966	65	89.7	204	324
293	14.11.1966	48.4	92.8	290	564
1,000 years	—	89.78	105.99	861	1,217
3.5	3.2.1966	First soft landing on the Moon			
1.8	2.2.1966	~52	~88	~170	~220
24.68	27.2.1966	75.05	90.64	185	425
70 years	—	97.91	100.35	702	845
7 years	—	82.09	94.83	508	512
8	18.2.1966	65	89.7	204	322
282	21.11.1966	48.9	95.3	227	865
7.44	23.2.1966	96.54	89.00	148	293
200 years	—	34.03	118.51	499	2,738
8	27.2.1966	65	89.5	209	309
22	16.3.1966	51.9	95.3	187	904
10,000 years	—	101.0	113.57	1,356	1,418
2	3.3.1966	51.85	88.6	191	226
18.83	29.3.1966	75.03	90.59	178	432
547.7	15.9.1967	28.88	90.20	285	298
0.44	17.3.1966	28.91	88.60	159	265
8	25.3.1966	72	92.1	214	565
4.92	23.3.1966	101.01	88.87	152	284
8	29.3.1966	65	89.6	210	327
300 years	—	89.73	105.37	891	1,128
1,000 years	—	144.53	103.85	879	1,011

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
429	USA	OV-1-5	1966 25B	30.3.1966	1
430	USA	US Air Force	1966 26A	31.3.1966	5
431	USSR	Luna-10	1966 27A	31.3.1966	1
		Heavy satellite	1966 27B	31.3.1966	—
432	USSR	Cosmos-114	1966 28A	6.4.1966	4
433	USA	US Air Force	1966 29A	7.4.1966	—
434	USA	Surveyor (model 2)	1966 30A	8.4.1966	1
435	USA	OAO-1	1966 31A	8.4.1966	2
436	USA	US Air Force	1966 32A	19.4.1966	1
437	USSR	Cosmos-115	1966 33A	20.4.1966	1
438	USA	OV-3-1	1966 34A	22.4.1966	3
439	USSR	Molniya-1	1966 35A	25.4.1966	4
440	USSR	Cosmos-116	1966 36A	26.4.1966	1
441	USSR	Cosmos-117	1966 37A	6.5.1966	4
442	USSR	Cosmos-118	1966 38A	11.5.1966	1
443	USA	US Air Force	1966 39A	14.5.1966	2
444	USA	Nimbus-2	1966 40A	15.5.1966	1
445	USA	US Air Force	1966 41A	19.5.1966	4
446	USA	US Air Force	1966 42A	24.5.1966	—
447	USSR	Cosmos-119	1966 43A	24.5.1966	—
448	USA	Explorer-32 (AE-B)	1966 44A	25.5.1966	2
449	USA	Surveyor-1	1966 45A	30.5.1966	—
450	USA	AT-DA	1966 46A	1.6.1966	57
451	USA	Gemini-9	1966 47A	3.6.1966	1
452	USA	US Air Force	1966 48A	3.6.1966	1
453	USA	OGO-3	1966 49A	7.6.1966	1
454	USSR	Cosmos-120	1966 50A	8.6.1966	3
455	USA	US Air Force	1966 51A	9.6.1966	—
		Secor-6 (EGRS-6)	1966 51B	9.6.1966	1
		ORS-2 (ERS-16)	1966 51C	9.6.1966	—
456	USA	OV-3-4	1966 52A	10.6.1966	3
457	USA	GGTS	1966 53A	16.6.1966	1
		IDCSP-1	1966 53B	16.6.1966	—
		IDCSP-2	1966 53C	16.6.1966	—

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
1,000 years	—	144.66	105.48	996	1,048
30 years	—	98.60	100.56	634	933
First moon satellite		71.9	178	351	1,014
3	4.4.1966	51.8	88.52	195	212
8	14.4.1966	73	90.1	210	374
18.43	26.4.1966	75.06	89.56	193	312
27.22	5.5.1966	30.71	89.50	175	334
500 years	—	35.03	100.71	792	806
6	26.4.1966	116.95	89.94	145	398
8	28.4.1966	65	89.3	190	294
200 years	—	82.47	151.8	351	5,741
6.5 years	—	64.5	710	499	39,500
221	3.12.1966	48.42	92	294	478
8	14.5.1966	65	89.5	207	308
60 years	—	65	97.1	~ 640	~ 640
6	21.5.1966	110.55	89.40	133	358
1,000 years	—	100.35	108.15	1,103	1,179
200 years	—	90.0	103.48	863	980
16	9.6.1966	66.04	89.00	179	271
190	30.11.1966	48.5	99.8	219	1,305
20	—	64.66	116.01	289	2,716
2.63	2.6.1966	Soft landing on the Moon			
40	11.7.1966	28.87	90.24	292	296
3.01	6.7.1966	28.86	89.80	270	272
6.17	9.6.1966	87.01	88.87	143	288
10 years	—	31.39	2915.0	319	122,173
8	16.6.1966	51.8	89.4	200	300
176.8	3.12.1966	90.05	124.89	174	3,316
391.7	6.7.1967	90.05	125.13	168	3,648
215.4	12.3.1967	90.03	125.02	179	3,623
600 years	—	40.77	142.99	641	4,718
$> 10^6$ years	—	0.104	1334.2	33,648	33,889
$> 10^6$ years	—	0.086	1334.7	33,656	33,897
$> 10^6$ years	—	0.081	1335.3	33,668	33,909

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
457	USA	IDCSP-3	1966 53D	16.6.1966	—
		IDCSP-4	1966 53E	16.6.1966	—
		IDCSP-5	1966 53F	16.6.1966	—
		IDCSP-6	1966 53G	16.6.1966	—
		IDCSP-7	1966 53H	16.6.1966	—
458	USSR	Cosmos-121	1966 54A	17.6.1966	4
459	USA	US Air Force	1966 55A	21.6.1966	1
460	USA	Pegasus-1	1966 56A	24.6.1966	3
461	USSR	Cosmos-122	1966 57A	25.6.1966	1
462	USA	Explorer-33 (IMP-4)	1966 58A	1.7.1966	4
463	USA	Saturn SA-203	1966 59A	5.7.1966	37
464	USSR	Proton-3	1966 60A	6.7.1966	3
465	USSR	Cosmos-123	1966 61A	8.7.1966	1
466	USA	US Air Force	1966 62A	12.7.1966	1
467	USA	OV-1-8	1966 63A	14.7.1966	5
468	USSR	Cosmos-124	1966 64A	14.7.1966	4
469	USA	Agena-10	1966 65A	18.7.1966	—
470	USA	Gemini-10	1966 66A	18.7.1966	10
471	USSR	Cosmos-125	1966 67A	20.7.1966	1
472	USSR	Cosmos-126	1966 68A	28.7.1966	2
473	USA	Titan-3B	1966 69A	29.7.1966	—
474	USA	OV-3-3	1966 70A	4.8.1966	3
475	USSR	Cosmos-127	1966 71A	8.8.1966	1
476	USA	US Air Force	1966 72A	9.8.1966	1
477	USA	Lunar Orbiter-1	1966 73A	10.8.1966	1
478	USA	US Air Force	1966 74A	16.8.1966	1
		Capsule	1966 74B	16.8.1966	—
479	USA	Pioneer-7	1966 75A	17.8.1966	4
480	USA	US Air Force	1966 76A	18.8.1966	3
481	USA	US Air Force	1966 77A	19.8.1966	—
		Secor-7 (EGRS-7)	1966 77B	19.8.1966	—
		ORS-1 (ERS-15)	1966 77C	19.8.1966	—
482	USSR	Luna-11	1966 78A	24.8.1966	1
		Heavy satellite	1966 78B	24.8.1966	—

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
$>10^6$ years	—	0.121	1336.6	33 695	33,936
$>10^6$ years	—	0.183	1338.6	33,696	34,018
$>10^6$ years	—	0.042	1340.8	33,699	34,102
$>10^6$ years	—	0.058	1344.0	33,722	34,206
$>10^6$ years	—	0.040	1347.6	33,712	34,359
8	25.6.1966	72.9	89.9	210	354
22	14.7.1966	80.10	90.15	194	367
20 years	—	87.14	181.43	4,207	4,271
50 years	—	65	97.1	625	625
$>10^6$ years	—	29.0	19,488	30,532	494,230
0.23	5.7.1966	31.98	88.31	183	212
72	16.9.1966	63.5	92.5	190	630
155	10.12.1966	48.8	92.2	263	529
7	20.7.1966	95.52	88.25	137	236
20 years	—	144.27	105.12	998	1,013
8	22.7.1966	51.8	89.4	208	303
163.93	29.12.1966	28.85	90.23	290	296
2.95	21.7.1966	28.85	88.64	160	268
13	2.8.1966	65	89.5	250	250
9	6.8.1966	51.8	90	212	359
7	6.8.1966	94.12	88.58	158	250
100 years	—	81.44	137.01	360	4,492
8	16.8.1966	51.9	89.2	204	279
32.20	11.9.1966	100.12	89.35	194	287
Lunar orbit***		12.16	217.4	192	1,867
7.5	24.8.1966	93.24	89.58	146	358
10 years	—	93.17	94.99	510	524
Heliocentric orbit		0.09	402.95	$151 \cdot 10^6$	$168 \cdot 10^6$
10,000 years	—	88.86	106.85	1,056	1,101
100,000 years	—	90.07	167.59	3,680	3,700
100,000 years	—	90.11	167.59	3,680	3,700
100,000 years	—	90.11	167.56	3,670	3,720
Lunar orbit		27	~180	160	1,200
1.4	25.8.1966	51.86	88.12	177	190

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
483	USSR	Cosmos-128	1966 79A	27.8.1966	1
484	USA	Agena-11	1966 80A	12.9.1966	—
485	USA	Gemini-11	1966 81A	12.9.1966	3
486	USA	US Air Force	1966 82A	16.9.1966	1
487	USA	US Air Force	1966 83A	16.9.1966	2
		Capsule	1966 83A	16.9.1966	—
488	USA	Surveyor-2	1966 84A	20.9.1966	—
489	USA	US Air Force	1966 85A	20.9.1966	1
490	USA	Titan-3B	1966 86A	28.9.1966	—
491	USA	ESSA-3	1966 87A	2.10.1966	3
492	No data		1966 88A	17.9.1966	56
493	USA	Secor-8 (EGRS-8)	1966 89B	5.10.1966	
		US Air Force	1966 89A	5.10.1966	—
494	USA	US Air Force	1966 90A	12.10.1966	2
		US Air Force	1966 90B	12.10.1966	—
495	USSR	Cosmos-129	1966 91A	14.10.1966	1
496	USSR	Molniya-1	1966 92A	20.10.1966	2
497	USSR	Cosmos-130	1966 93A	20.10.1966	1
498	USSR	Luna-12	1966 94A	22.10.1966	1
		Heavy satellite	1966 94B	22.10.1966	—
499	USA	Surveyor (model 3)	1966 95A	26.10.1966	1
500	USA	Intelsat-2	1966 96A	26.10.1966	1
501	USA	OV-3-2	1966 97A	28.10.1966	3
502	USA	US Air Force	1966 98A	2.11.1966	1
503	USA	MOL (model)	1966 99A	3.11.1966	—
		OV-4-1R	1966 99B	3.11.1966	—
		OV-1-6	1966 99C	3.11.1966	—
		OV-4-1T	1966 99D	3.11.1966	—
504	USA	Lunar Orbiter-2	1966 100A	6.11.1966	1
505	No data		1966 101A	2.11.1966	44
506	USA	US Air Force	1966 102A	8.11.1966	—
507	USA	Agena-12	1966 103A	11.11.1966	—
508	USA	Gemini-12	1966 104A	11.11.1966	16
509	USSR	Cosmos-131	1966 105A	12.11.1966	1

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
8	4.9.1966	65	90	212	364
108.76	30.12.1966	28.83	90.35	298	298
2.97	15.9.1966	28.83	88.78	161	280
50 years	—	98.46	100.86	705	891
6	23.9.1966	93.98	89.37	148	333
601	9.5.1968	94.06	94.25	460	501
—	23.9.1966	Lunar impact			
21.9	12.10.1966	85.13	90.87	188	442
9.06	7.10.1966	93.98	89.01	151	296
10,000 years	—	101.06	114.60	1,383	1,493
54.45	11.11.1966	49.63	96.08	163	1,046
100,000 years	—	90.19	167.63	3,676	3,706
100,000 years	—	90.20	167.63	3,682	3,702
8	20.10.1966	90.96	89.00	155	287
8.46	21.10.1966	90.88	88.99	181	258
7	21.10.1966	65	89.4	202	307
692	11.9.1968	64.9	713	485	39,700
8	28.10.1966	65	89.8	211	340
	Lunar orbit		205	100	1,740
2.49	24.10.1966	51.92	88.58	199	212
11	6.11.1966	29.9	—	~ 200	~ 470,000
$> 10^6$ years	—	17.22	730	3,424	37,531
10 years	—	81.97	104.24	320	1,597
7	10.11.1966	90.96	89.20	159	305
66.9	9.1.1967	32.82	90.42	298	305
62.56	5.1.1967	32.84	90.30	291	298
57.71	31.12.1966	32.84	90.27	290	295
68.6	11.1.1967	32.83	90.59	294	321
Several years		Lunar satellite		50	1,850
15	17.11.1966	49.58	94.50	140	855
20.6	29.11.1966	100.09	89.42	172	318
41	23.12.1966	28.78	89.93	243	310
3.93	15.11.1966	28.78	89.93	243	310
8	20.11.1966	72.9	89.9	205	360

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
510	USSR	Cosmos-132	1966 106A	19.11.1966	1
511	USSR	Cosmos-133	1966 107A	28.11.1966	1
512	USSR	Cosmos-134	1966 108A	3.12.1966	2
513	USA	US Air Force	1966 109A	5.12.1966	1
514	USA	ATS-1	1966 110A	7.12.1966	1
515	USA	OV-1-9	1966 111A	11.12.1966	1
		OV-1-10	1966 111B	11.12.1966	1
516	USSR	Cosmos-135	1966 112A	12.12.1966	3
517	USA	Titan-3B	1966 113A	14.12.1966	—
518	USA	Bios-1	1966 114A	14.12.1966	3
519	USSR	Cosmos-136	1966 115A	19.12.1966	1
520	USSR	Luna-13	1966 116A	21.12.1966	1
		Heavy satellite	1966 116B	21.12.1966	—
521	USSR	Cosmos-137	1966 117A	21.12.1966	1
522	USA	US Air Force	1966 118A	29.12.1966	2
523	USA	Intelsat-2	1967 01A	11.1.1967	3
524	USA	US Air Force	1967 02A	14.1.1967	1
525	USA	IDCSP-8	1967 03A	18.1.1967	1
		IDCSP-9	1967 03B	18.1.1967	—
		IDCSP-10	1967 03C	18.1.1967	—
		IDCSP-11	1967 03D	18.1.1967	—
		IDCSP-12	1967 03E	18.1.1967	—
		IDCSP-13	1967 03F	18.1.1967	—
		IDCSP-14	1967 03G	18.1.1967	—
		IDCSP-15	1967 03H	18.1.1967	—
526	USSR	Cosmos-138	1967 04A	19.1.1967	1
527	USSR	Cosmos-139	1967 05A	25.1.1967	2
528	USA	ESSA-4	1967 06A	26.1.1967	1
529	USA	US Air Force	1967 07A	2.2.1967	1
530	USA	Lunar Orbiter-3	1967 08A	4.2.1967	1
531	USSR	Cosmos-140	1967 09A	7.2.1967	1
532	USA	US Air Force	1967 10A	8.2.1967	1
533	France	Diademe-1	1967 11A	8.2.1967	15
534	USSR	Cosmos-141	1967 12A	8.2.1967	1

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
8	27.11.1966	65	89.3	207	280
2	30.11.1966	51.9	88.4	181	232
8	11.12.1966	65	89.6	214	319
8	14.12.1966	104.63	89.77	137	388
$> 10^6$ years	—	0.23	1465.89	35,852	36,887
200 years	—	99.14	142.30	473	4,824
25 years	—	93.43	98.00	641	769
120	12.4.1967	48.5	93.5	259	662
9	24.12.1966	109.56	89.58	138	368
62.35	15.2.1967	33.51	90.44	295	309
8	27.12.1966	64.6	89.4	198	305
	24.12.1966		Soft landing on the Moon		
1.85	23.12.1966	51.8	88.4	171	223
337	23.11.1967	48.8	104.3	230	1,720
828	5.4.1969	75.03	94.41	486	496
$> 10^6$ years	—	2.14	1448.5	35,563	36,496
18.7	2.2.1967	80.07	90.13	180	380
$> 10^6$ years	—	0.07	1329.6	33,557	33,800
$> 10^6$ years	—	0.05	1330.0	35,526	33,846
$> 10^6$ years	—	0.06	1330.7	33,579	33,819
$> 10^6$ years	—	0.07	1332.1	33,606	33,847
$> 10^6$ years	—	0.03	1334.2	33,608	33,929
$> 10^6$ years	—	0.06	1336.5	33,656	33,978
$> 10^6$ years	—	0.03	1339.5	33,675	34,077
$> 10^6$ years	—	0.05	1343.0	33,665	34,229
7.7	27.1.1967	65	89.2	193	293
0.06	25.1.1967	50	~ 88	144	210
10,000 years	—	102.0	113.48	1,328	1,443
9	12.2.1967	102.9	89.47	136	357
	Lunar satellite			200	1,850
2	9.2.1967	51.7	88.48	170	241
70 years	—	98.84	101.55	796	868
100 years	—	40.02	104.66	557	1,411
8	16.2.1967	72.9	89.8	210	345

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
535	USSR	Cosmos-142	1967 13A	14.2.1967	1
536	France	Diademe-2	1967 14A	15.2.1967	5
537	USA	US Air Force	1967 15A	22.2.1967	—
538	USA	Titan-5B	1967 16A	24.2.1967	—
539	USSR	Cosmos-143	1967 17A	27.2.1967	1
540	USSR	Cosmos-144	1967 18A	28.2.1967	1
541	USSR	Cosmos-145	1967 19A	3.3.1967	1
542	USA	OSO-3	1967 20A	8.3.1967	1
543	USSR	Cosmos-146	1967 21A	10.3.1967	2
544	USSR	Cosmos-147	1967 22A	13.3.1967	1
545	USSR	Cosmos-148	1967 23A	16.3.1967	1
546	USSR	Cosmos-149	1967 24A	21.3.1967	19
547	USSR	Cosmos-150	1967 25A	22.3.1967	1
548	USA	Intelsat-2C	1967 26A	23.3.1967	2
549	USSR	Cosmos-151	1967 27A	24.3.1967	3
550	USSR	Cosmos-152	1967 28A	25.3.1967	1
551	USA	US Air Force	1967 29A	30.3.1967	—
552	USSR	Cosmos-153	1967 30A	4.4.1967	1
553	USA	ATS-2	1967 31A	6.4.1967	1
554	USSR	Cosmos-154	1967 32A	8.4.1967	2
555	USSR	Cosmos-155	1967 33A	12.4.1967	3
556	USA	US Air Force	1967 34A	14.4.1967	1
557	USA	Surveyor-3	1967 35A	17.4.1967	1
558	USA	ESSA-5	1967 36A	20.4.1967	3
559	USSR	Soyuz-1	1967 37A	23.4.1967	1
560	Italy, USA	San-Marco-2	1967 38A	26.4.1967	1
561	USSR	Cosmos-156	1967 39A	27.4.1967	1
562	USA	Vela-Hotel-7	1967 40A	28.4.1967	1
		Vela-Hotel-8	1967 40B	28.4.1967	—
		ERS-18	1967 40C	28.4.1967	—
		ERS-20	1967 40D	28.4.1967	—
		ERS-27	1967 40E	28.4.1967	—
563	USA	Lunar Orbiter-4	1967 41A	4.5.1967	1
564	UK, USA	Ariel-3	1967 42A	5.5.1967	1

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
142	6.7.1967	48.4	100.3	214	1,362
100 years	—	39.52	109.0	589	1,784
17.02	11.3.1967	80.03	90.12	180	380
10.15	6.3.1967	106.98	90.02	135	414
8	7.3.1967	65	89.5	204	302
50 years	—	81.2	96.92	~ 625	~ 625
371	8.3.1968	48.4	108.6	220	2,135
40 years	—	32.87	95.53	534	564
1	11.3.1967	51.5	89.2	190	310
8	21.3.1967	65	89.5	198	317
52	7.5.1967	71	91.3	275	436
17	7.4.1967	48.4	89.4	248	297
8	30.3.1967	65.7	90.1	206	373
$> 10^6$ years	—	1.37	1,434	35,687	35,771
50 years	—	56	97.1	~ 630	~ 630
132	5.8.1967	71	92.2	283	512
17	17.4.1967	85.03	89.45	167	326
8	12.4.1967	64.6	89.3	202	291
3 years	—	28.40	218.9	178	11,124
2	10.4.1967	51.6	88.5	186	232
8	20.4.1967	51.8	89.2	203	286
1,000 years	—	90.23	106.60	1,053	1,083
2.6	19.4.1967	Soft landing on the Moon			
10,000 years	—	101.97	113.63	1,361	1,423
1.11	24.4.1967	51.67	88.6	201	224
171.1	14.10.1967	2.89	93.93	217	738
50 years	—	81.2	97	~ 630	~ 630
$> 10^6$ years	—	33.06	6671.8	107,337	114,612
$> 10^6$ years	—	33.06	6671.8	107,337	114,612
$> 10^6$ years	—	32.8	2829.6	8,604	111,229
$> 10^6$ years	—	32.8	2829.6	8,604	111,229
$> 10^6$ years	—	32.8	2829.6	8,604	111,229
Moon satellite					
10 years	—	80.17	95.69	497	608

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
565	USA	US Air Force	1967 43A	9.5.1967	1
		Capsule	1967 43B	9.5.1967	—
566	USSR	Cosmos-157	1967 44A	12.5.1967	4
567	USSR	Cosmos-158	1967 45A	15.5.1967	3
568	USSR	Cosmos-159	1967 46A	16.5.1967	5
569	USSR	Cosmos-160	1967 47A	17.5.1967	1
570	USA	US Air Force	1967 48A	18.5.1967	1
571	USSR	Cosmos-161	1967 49A	22.5.1967	1
572	USA	US Air Force	1967 50B	22.5.1967	1
573	USA	Explorer-34 (IMP-5)	1967 51A	24.5.1967	2
574	USSR	Molniya-1	1967 52A	24.5.1967	3
		Heavy satellite	1967 52C	24.5.1967	—
575	USA	Surcal	1967 53B	31.5.1967	1
		GGSE-4	1967 53C	31.5.1967	—
		GGSE-5	1967 53D	31.5.1967	—
		US Air Force	1967 53E	31.5.1967	—
		Surcal	1967 53F	31.5.1967	—
		US Air Force	1967 53G	31.5.1967	—
		US Air Force	1967 53H	31.5.1967	—
		Surcal 150B	1967 53J	31.5.1967	—
576	USSR	Cosmos-162	1967 54A	1.6.1967	2
577	USA	US Air Force	1967 55A	4.6.1967	1
578	USSR	Cosmos-163	1967 56A	5.6.1967	1
579	USSR	Cosmos-164	1967 57A	8.6.1967	2
580	USSR	Venyera-4	1967 58A	12.6.1967	2
		Heavy satellite	1967 58B	12.6.1967	—
581	USSR	Cosmos-165	1967 59A	12.6.1967	1
582	USA	Mariner-5	1967 60A	14.6.1967	1
583	USSR	Cosmos-166	1967 61A	16.6.1967	1
584	USA	US Air Force	1967 62A	16.6.1967	1
585	USSR	Cosmos-167	1967 63A	17.6.1967	5
586	USA	US Air Force	1967 64A	20.6.1967	—
587	USA	Secor-9	1967 65A	29.6.1967	—
		Aurora-1	1967 65B	29.6.1967	—

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
65	13.7.1967	85.10	94.36	200	777
20 years	—	85.10	98.38	555	809
8	20.5.1967	51.3	89.4	202	296
200 years	—	74.04	100.68	~ 850	~ 850
20 years	—	51.83	1,173	380	60,600
1	18.5.1967	49.6	~ 88	142	205
1,000 years	—	89.57	107.04	1,074	1,105
8	30.5.1967	65.7	89.8	205	343
4.9	27.5.1967	91.49	88.42	148	240
3 years	—	67.17	6846.1	242	214,383
4.5 years	—	64.8	715	460	39,810
22	15.6.1967	64.85	91.26	230	472
1,000 years	—	69.98	103.55	919	934
1,000 years	—	69.98	103.45	915	929
1,000 years	—	69.98	103.45	915	929
1,000 years	—	69.98	103.45	914	928
1,000 years	—	69.98	103.45	914	928
1,000 years	—	69.98	103.45	914	928
1,000 years	—	69.98	103.45	914	928
1,000 years	—	69.98	103.45	914	928
8	9.6.1967	51.8	89.2	201	280
8	12.6.1967	104.88	90.57	149	456
128	11.10.1967	48.4	93.1	261	616
6	14.6.1967	65.7	89.5	202	320
	18.10.1967	First soft landing on Venus			
1.76	13.6.1967	51.8	87.92	162	188
217	15.1.1968	81.9	102.1	211	1,542
		Heliocentric orbit			
131	25.10.1967	48.4	92.9	283	578
33.16	20.7.1967	80.02	89.97	181	367
8	25.6.1967	51.8	89.2	201	286
10	30.6.1967	111.40	89.01	127	325
10,000 years	—	89.91	172.2	3,803	3,947
10,000 years	—	89.82	172.18	3,800	3,947

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
588	USA	IDSCP-3-1	1967 66A	1.7.1967	1
		IDSCP-3-2	1967 66B	1.7.1967	—
		IDSCP-3-3	1967 66C	1.7.1967	—
		IDSCP-3-4	1967 66D	1.7.1967	—
		LES-5	1967 66E	1.7.1967	—
		Dodge-1	1967 66F	1.7.1967	—
589	USSR	Cosmos-168	1967 67A	4.7.1967	2
590	USA	Surveyor-4	1967 68A	13.7.1967	1
591	USSR	Cosmos-169	1967 69A	17.7.1967	4
592	USA	Explorer-35 (IMP-6)	1967 70A	19.7.1967	2
593	USA	US Air Force	1967 71A	25.7.1967	2
594	USA	OV-1-86	1967 72A	27.7.1967	2
		OV-1-12	1967 72D	27.7.1967	1
595	USA	OGO-4	1967 73A	28.7.1967	1
596	USSR	Cosmos-170	1967 74A	31.7.1967	4
597	USA	Lunar Orbiter-5	1967 75A	1.8.1967	1
598	USA	US Air Force	1967 76A	7.8.1967	1
599	USSR	Cosmos-171	1967 77A	8.8.1967	4
600	USSR	Cosmos-172	1967 78A	9.8.1967	1
601	USA	US Air Force	1967 79A	16.8.1967	1
602	USA	US Air Force	1967 80A	23.8.1967	1
603	USSR	Cosmos-173	1967 81A	24.8.1967	1
604	USSR	Cosmos-174	1967 82A	31.8.1967	3
605	USA	Bios-2	1967 83A	7.9.1967	1
		Capsule	1967 83C	7.9.1967	—
606	USA	Surveyor-5	1967 84A	8.9.1967	1
607	USSR	Cosmos-175	1967 85A	11.9.1967	2
608	USSR	Cosmos-176	1967 86A	12.9.1967	13
609	USA	US Air Force	1967 87A	15.9.1967	—
610	USSR	Cosmos-179	1967 88A	16.9.1967	1
611	USSR	Cosmos-178	1967 89A	19.9.1967	3
612	USA	US Air Force	1967 90A	19.9.1967	—
613	USSR	Cosmos-179	1967 91A	22.9.1967	2
614	USA	US Air Force	1967 92A	25.9.1967	2

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
$>10^6$ years	—	7.18	1308.9	32,986	33,528
$>10^6$ years	—	7.22	1309.8	33,006	33,548
$>10^6$ years	—	7.2	1311.6	33,079	33,555
$>10^6$ years	—	7.1	1313.6	33,156	33,553
$>10^6$ years	—	7.1	1313.6	33,156	33,553
$>10^6$ years	—	7.1	1313.6	33,156	33,553
8	12.7.1967	51.8	89.1	199	268
2.6	16.7.1967	Fall to the Moon			
0.06	17.7.1967	50	88.8	144	208
Moon satellite					
7 years	—	75.08	94.30	390	582
15 years	—	101.72	95.48	480	604
12 years	—	101.62	95.62	542	556
40 years	—	86.03	97.89	411	903
0.06	31.7.1967	50	~88	145	208
Moon satellite					
25	1.9.1967	79.94	89.72	174	346
0.06	8.8.1967	50	~88	145	220
8	17.8.1967	51.8	89.4	202	301
13	29.8.1967	111.8	90.43	142	449
100 years	—	98.97	102.20	834	892
115	17.12.1967	71	92.3	280	528
487	30.12.1968	64.5	715	500	39,750
26.19	4.10.1967	33.46	90.38	286	313
1.87	9.9.1967	32.94	92.08	315	450
2.6	11.9.1967	Soft landing on the Moon			
8	19.9.1967	72.9	92.2	210	386
173	3.3.1968	81.9	102.5	206	1,581
18.69	4.10.1967	80.07	89.95	150	389
8	24.9.1967	51.8	89.3	202	292
0.06	19.9.1967	50	~88	145	205
10.2	30.9.1967	106.10	89.75	122	401
0.06	22.9.1967	50	~88	145	208
1,000 years	—	89.28	106.81	1,041	1,116

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
615	USSR	Cosmos-180	1967 93A	26.9.1967	1
616	USA	Intelsat-2	1967 94A	28.9.1967	3
617	USSR	Molniya-1	1967 95A	3.10.1967	5
618	USA	US Air Force	1967 96A	11.10.1967	1
619	USSR	Cosmos-181	1967 97A	11.10.1967	1
620	USSR	Cosmos-182	1967 98A	16.10.1967	2
621	USSR	Cosmos-183	1967 99A	18.10.1967	2
622	USA	OSO-4	1967 100A	18.10.1967	1
623	USSR	Molniya-1	1967 101A	22.10.1967	4
624	USSR	Cosmos-184	1967 102A	25.10.1967	1
625	USA	US Air Force	1967 103A	25.10.1967	—
626	USSR	Cosmos-185	1967 104A	27.10.1967	1
627	USSR	Cosmos-186	1967 105A	27.10.1967	1
628	USSR	Cosmos-187	1967 106A	28.10.1967	2
629	USSR	Cosmos-188	1967 107A	30.10.1967	1
630	USSR	Cosmos-189	1967 108A	30.10.1967	4
631	USA	US Air Force	1967 109A	2.11.1967	1
632	USSR	Cosmos-190	1967 110A	3.11.1967	1
633	USA	ATS-3	1967 111A	5.11.1967	1
634	USA	Surveyor-6	1967 112A	6.11.1967	1
635	USA	Apollo-4	1967 113A	9.11.1967	1
636	USA	ESSA-6	1967 114A	10.11.1967	3
637	USSR	Cosmos-191	1967 115A	21.11.1967	1
638	USSR	Cosmos-192	1967 116A	23.11.1967	1
639	USSR	Cosmos-193	1967 117A	25.11.1967	1
640	Australia-USA	WRESAT	1967 118A	29.11.1967	—
641	USSR	Cosmos-194	1967 119A	3.12.1967	1
642	USA	OV 3-6	1967 120A	5.12.1967	4
643	USA	US Air Force	1967 121A	5.12.1967	—
644	USA	US Air Force	1967 122A	9.12.1967	—
645	USA	Pioneer-8	1967 123A	13.12.1967	—
		TTS-1	1967 123B	13.12.1967	3
646	USSR	Cosmos-195	1967 124A	16.12.1967	2

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
8	4.10.1967	72.9	90.1	212	370
$>10^6$ years	—	0.93	1438.3	35,747	35,913
519	5.3.1969	65	712	465	39,600
80 years	—	99.09	100.18	694	837
8	19.10.1967	65.6	89.7	200	344
8	24.10.1967	65	89.9	210	355
0.1	18.10.1967	50	88.9	145	212
40 years	—	33.04	95.58	546	560
2 years	—	64.7	714	456	39,740
60 years	—	81.2	97.14	~ 635	~ 635
9	4.11.1967	111.57	90.15	136	429
445	14.1.1969	64.1	98.7	522	888
4	31.10.1967	51.7	88.7	209	235
0.1	28.10.1967	50	88.88	145	210
3	2.11.1967	51.68	88.97	200	276
50 years	—	74	95.7	535	600
30	2.12.1967	81.53	90.47	183	410
8	11.11.1967	65.7	89.8	201	347
$>10^6$ years	—	0.53	1444.9	35,791	36,130
4	10.11.1967	Soft landing on the Moon			
0.36	9.11.1967	32.7	88.10	187	187
10,000 years	—	102.12	114.82	1410	1488
102	3.03.1968	71	92.2	281	518
80 years	—	74	99.9	~ 760	~ 760
8	3.12.1967	65.7	89.9	203	354
42	10.1.1968	83.35	99.27	193	1259
8	11.12.1967	65.7	89.7	205	333
460	9.3.1969	90.67	93.14	412	439
11	16.12.1967	109.55	90.16	137	430
16	25.12.1967	81.65	88.45	158	237
Heliocentric orbit		0.5	385.5	~ 148	~ 168
137	29.4.1968	32.90	92.18	287	490
8	24.12.1968	65.7	90.1	211	375

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
647	USSR	Cosmos-196	1967 125A	19.12.1967	2
648	USSR	Cosmos-197	1967 126A	26.12.1967	9
649	USSR	Cosmos-198	1967 127A	27.12.1967	2
650	USA	Surveyor-7	1968 01A	7.1.1968	1
651	USA	Explorer-36	1968 02A	11.1.1968	3
652	USSR	Cosmos-199	1968 03B	16.1.1968	3
653	USA	US Air Force	1968 04A	17.1.1968	2
654	USA	US Air Force	1968 05A	18.1.1968	—
655	USSR	Cosmos-200	1968 06A	20.1.1968	7
656	USA	Apollo-5	1968 07A	22.1.1968	2
657	USA	US Air Force	1968 08A	24.1.1968	2
658	USSR	Cosmos-201	1968 09A	6.2.1968	1
659	USSR	Cosmos-202	1968 10A	20.2.1968	1
660	USSR	Cosmos-203	1968 11A	20.2.1968	1
661	USA	US Air Force	1968 12A	2.3.1968	3
662	USSR	Zond-4	1968 13A	2.3.1968	3
663	USA	OGO-5	1968 14A	4.3.1968	1
664	USSR	Cosmos-204	1968 15A	5.3.1968	1
665	USSR	Cosmos-205	1968 16A	5.3.1968	1
666	USA	Explorer-37	1968 17A	5.3.1968	3
667	USA	US Air Force	1968 18A	13.3.1968	—
668	USSR	Cosmos-206	1968 19A	14.3.1968	1
669	USA	US Air Force	1968 20A	14.3.1968	1
670	USSR	Cosmos-207	1968 21A	16.3.1968	1
671	USSR	Cosmos-208	1968 22A	21.3.1968	2
672	USSR	Cosmos-209	1968 23A	22.3.1968	4
673	USSR	Cosmos-210	1968 24A	3.4.1968	2
674	USA	Apollo-6	1968 25A	4.4.1968	18
675	USA	OV 1-13	1968 26A	6.4.1968	1
		OV 1-14	1968 26B	6.4.1968	1
676	USSR	Luna-14	1968 27A	7.4.1968	2
677	USSR	Cosmos-211	1968 28A	9.4.1968	1
678	USSR	Cosmos-212	1968 29A	14.4.1968	1
679	USSR	Cosmos-213	1968 30A	15.4.1968	1

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
203	7.7.1968	49	95.5	225	887
35	30.1.1968	48.5	91.5	220	505
500 years?	—	65.1	89.8	265	281
3	10.1.1968	Soft landing on the Moon			
10,000 years	—	105.80	112.28	1084	1577
16	1.2.1968	65.7	90.2	204	386
7 years	—	75.16	94.53	450	576
17	4.2.1968	111.52	89.91	138	404
50 years	—	74	95.2	~ 536	~ 536
21	12.2.1968	31.63	89.65	170	356
34	27.2.1968	81.48	90.55	176	430
8	14.2.1968	65	89.9	210	355
33	24.3.1968	48.4	91.5	220	502
3,000 years	—	74.08	109.4	~ 1200	~ 1200
1,000 years	—	89.99	107.0	1035	1139
Heliocentric orbit					
	—	31.13	3795.9	232	148,228
362	2.3.1969	71	95.9	282	873
8	13.3.1968	65.7	89.4	201	310
40 years	—	59.43	98.68	513	881
11	24.3.1968	99.87	89.87	128	407
60 years	—	81	97	~ 630	~ 630
27	10.4.1968	83.01	90.20	178	391
8	24.3.1968	65.6	89.8	210	342
12	2.4.1968	65	89.4	207	305
500 years	—	65.1	89.6	250	282
8	11.4.1968	81.2	90.3	217	395
0.42	4.4.1968	32.57	93.53	205	392
1,000 years	—	100.05	199.72	558	9316
1,000 years	—	100.04	208.03	571	9913
Lunar satellite		42	160	160	870
215	10.11.1968	81.9	102.5	210	1574
5	19.4.1968	51.7	88.75	210	239
5	20.4.1968	51.4	89.16	205	291

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
680	USA	US Air Force	1968 31A	17.4.1968	—
681	USSR	Cosmos-214	1968 32A	18.4.1968	1
682	USSR	Cosmos-215	1968 33A	19.4.1968	1
683	USSR	Cosmos-216	1968 34A	20.4.1968	1
684	USSR	Molniya-1	1968 35A	21.4.1968	3
685	USSR	Cosmos-217	1968 36A	24.4.1968	—
686	USSR	Cosmos-218	1968 37A	25.4.1968	2
687	USSR	Cosmos-219	1968 38A	26.4.1968	2
688	USA	US Air Force	1968 39A	1.5.1968	1
689	USSR	Cosmos-220	1968 40A	7.5.1968	2
690	Europe-USA	Iris (ESRO-2)	1968 41A	17.5.1968	2
691	USA	US Air Force	1968 42A	23.5.1968	1
692	USSR	Cosmos-221	1968 43A	24.5.1968	1
693	USSR	Cosmos-222	1968 44A	30.5.1968	1
694	USSR	Cosmos-223	1968 45A	1.6.1968	1
695	USSR	Cosmos-224	1968 46A	4.6.1968	1
696	USA	US Air Force	1968 47A	5.6.1968	—
697	USSR	Cosmos-225	1968 48A	12.6.1968	3
698	USSR	Cosmos-226	1968 49A	12.6.1968	1
699	USA	IDCSP 4-1	1968 50A	13.6.1968	1
		IDCSP 4-2	1968 50B	13.6.1968	—
		IDCSP 4-3	1968 50C	13.6.1968	—
		IDCSP 4-4	1968 50D	13.6.1968	—
		IDCSP 4-5	1968 50E	13.6.1968	—
		IDCSP 4-6	1968 50F	13.6.1968	—
		IDCSP 4-7	1968 50G	13.6.1968	—
		IDCSP 4-8	1968 50H	13.6.1968	—
700	USSR	Cosmos-227	1968 51A	18.6.1968	1
701	USA	US Air Force	1968 52A	20.6.1968	1
702	USSR	Cosmos-228	1968 53A	21.6.1968	6
703	USSR	Cosmos-229	1968 54A	26.6.1968	1
704	USA	Explorer-38	1968 55A	4.7.1968	2
705	USSR	Cosmos-230	1968 56A	5.7.1968	1
706	USSR	Molniya-1	1968 57A	5.7.1968	5

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
12	29.4.1968	111.51	90.10	134	427
8	26.4.1968	81.4	90.3	211	403
73	30.6.1968	48.5	91.1	261	426
8	28.4.1968	51.8	89.1	199	277
5.5 years	—	65	713	460	39,700
2	26.4.1968	62.2	93.4	396	520
0.1	25.4.1968	50	87.3	144	210
310	2.3.1969	48.4	104.7	222	1770
14	15.5.1968	83.05	88.58	164	243
50 years	—	74	99.2	670	760
5 years	—	97.16	99.00	334	1085
100 years	—	98.94	102.19	817	904
1 years	—	48.4	108.3	220	2108
134	11.10.1968	71	92.3	277	528
8	9.6.1968	72.9	90.1	212	374
8	12.6.1968	51.8	89	200	270
12	17.6.1968	110.52	90.31	123	456
144	2.11.1968	48.4	92.2	257	530
60 years	—	81.2	96.9	603	650
$>10^6$ years	—	0.19	1335.7	33,758	33,841
$>10^6$ years	—	0.11	1335.5	33,725	33,863
$>10^6$ years	—	0.10	1335.9	33,699	33,907
$>10^6$ years	—	0.10	1338.0	33,737	33,954
$>10^6$ years	—	0.19	1339.6	33,721	34,035
$>10^6$ years	—	0.16	1342.0	33,724	34,126
$>10^6$ years	—	0.17	1345.2	33,721	34,256
$>10^6$ years	—	0.13	1350.6	33,752	34,443
8	26.6.1968	51.8	89.1	194	281
25	16.7.1968	84.99	.89.75	193	326
12	3.7.1968	51.6	89	206	259
8	4.7.1968	72.8	89.9	210	354
100,000 years	—	120.64	224.41	5851	5861
120	11.11.1968	48.5	93	290	580
2 years	—	65	715	470	39,770

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
707	USSR	Cosmos-231	1968 58A	10.7.1968	1
708	USA	OV 1-15	1968 59A	11.7.1968	1
		OV 1-16	1968 59B	11.7.1968	1
709	USSR	Cosmos-232	1968 60A	16.7.1968	1
710	USSR	Cosmos-233	1968 61A	18.7.1968	1
711	USSR	Cosmos-234	1968 62A	30.7.1968	1
712	USA	US Air Force	1968 63A	6.8.1968	—
713	USA	US Air Force	1968 64A	6.8.1968	—
714	USA	US Air Force	1968 65A	7.8.1968	—
715	USA	Explorer-39	1968 66A	8.8.1968	8
		Explorer-40	1968 66B	8.8.1968	—
716	USSR	Cosmos-235	1968 67A	9.8.1968	1
717	USA	ATS-4	1968 68A	10.8.1968	—
718	USA	ESSA-7	1968 69A	16.8.1968	3
719	USSR	Cosmos-236	1968 70A	27.8.1968	1
720	USSR	Cosmos-237	1968 71A	27.8.1968	1
721	USSR	Cosmos-238	1968 72A	28.8.1968	1
722	USSR	Cosmos-239	1968 73A	5.9.1968	1
723	USA	US Air Force	1968 74A	10.9.1968	—
724	USSR	Cosmos-240	1968 75A	14.9.1968	1
725	USSR	Zond-5	1968 76A	15.9.1968	3
726	USSR	Cosmos-241	1968 77A	16.9.1968	1
727	USA	US Air Force	1968 78A	18.9.1968	1
728	USSR	Cosmos-242	1968 79A	20.9.1968	1
729	USSR	Cosmos-243	1968 80A	23.9.1968	2
730	USA	OV 2-5	1968 81A	26.9.1968	1
		ERS-28	1968 81B	26.9.1968	—
		ERS-21	1968 81C	26.9.1968	—
		LES-6	1968 81D	26.9.1968	—
731	USSR	Cosmos-244	1968 82A	2.10.1968	2
732	USSR	Cosmos-245	1968 83A	3.10.1968	1
733	Europe-USA	Aurora (ESRO-1)	1968 84A	3.10.1968	2
734	USSR	Molniya-1	1968 85A	5.10.1968	3
735	USA	US Air Force	1968 86A	5.10.1968	—
736	USSR	Cosmos-246	1968 87A	7.10.1968	1

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
8	18.7.1968	65	89.7	211	330
118	6.11.1968	89.90	104.82	154	1818
39	19.8.1968	90.0	91.77	163	554
8	24.7.1968	65	89.8	202	352
204	7.2.1969	82	102.1	210	1545
6	5.8.1968	51.8	89.5	210	310
20 years	—	9.9	1436	31,680	39,860
10	16.8.1968	110.00	89.85	142	395
20	27.8.1968	82.11	88.60	152	257
10 years	—	80.67	118.33	670	2538
500 years	—	80.67	118.33	681	2533
8	17.8.1968	51.8	89.4	207	303
68	17.10.1968	29.04	93.92	219	726
10,000 years	—	101.72	115.32	1469	1472
50 years	—	56	96.9	600	655
8	4.9.1968	65.4	89.7	201	343
4	1.9.1968	51.7	88.5	199	219
8	13.9.1968	51.8	89.2	202	282
15	25.9.1968	106.06	89.82	125	404
3	17.9.1968	51.8	89.3	197	293
6	21.9.1968	Moon fly-by and return			
8	24.9.1968	65.4	89.7	201	343
20	8.10.1968	83.02	90.12	167	393
54	13.11.1968	71	91.3	280	440
11	4.10.1968	71.3	89.6	210	319
$> 10^6$ years	—	2.9	1418	35,116	35,816
~ 7 years	—	26.37	630.3	184	35,787
$> 10^6$ years	—	3	1435.8	35,776	35,785
$> 10^6$ years	—	3	1431.1	35,597	35,785
0.06	2.10.1968	50	87.3	140	212
104	16.1.1969	71	92.1	282	509
18 months	—	93.74	103.04	260	1540
5 years	—	65	712	490	39,600
7 years	—	74.97	94.55	483	511
5	12.10.1968	65.4	89.4	147	348

Appendix I

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit*
737	USSR	Cosmos-247	1968 88A	11.10.1968	1
738	USA	Apollo-7	1968 89A	11.10.1968	1
739	USSR	Cosmos-248	1968 90A	19.10.1968	4
740	USSR	Cosmos-249	1968 91A	20.10.1968	56
741	USA	US Air Force	1968 92A	23.10.1968	—
742	USSR	Soyuz-2	1968 93A	25.10.1968	1
743	USSR	Soyuz-3	1968 94A	26.10.1968	1
744	USSR	Cosmos-250	1968 95A	31.10.1968	5
745	USSR	Cosmos-251	1968 96A	31.10.1968	3
746	USSR	Cosmos-252	1968 97A	1.11.1968	32
747	USA	US Air Force	1968 98A	3.11.1968	—
748	USA	US Air Force	1968 99A	6.11.1968	—
749	USA	Pioneer-9	1968 100A	8.11.1968	3
		TTS-2	1968 100B	8.11.1968	—
750	USSR	Zond-6	1968 101A	10.11.1968	4
751	USSR	Cosmos-253	1968 102A	13.11.1968	1
752	USSR	Proton-4	1968 103A	16.11.1968	1
753	USSR	Cosmos-254	1968 104A	21.11.1968	1
754	USSR	Cosmos-255	1968 105A	29.11.1968	1
755	USSR	Cosmos-256	1968 106A	30.11.1968	1
756	USSR	Cosmos-257	1968 107A	3.12.1968	1
757	USA	US Air Force	1968 108A	4.12.1968	—
758	GFR-USA	Heos-1	1968 109A	5.12.1968	1
759	USA	OAO-2	1968 110A	7.12.1968	1
760	USSR	Cosmos-258	1968 111A	10.12.1968	1
761	USA	US Air Force	1968 112A	12.12.1968	4
762	USSR	Cosmos-259	1968 113A	14.12.1968	2
763	USA	ESSA-8	1968 114A	15.12.1968	3
764	USSR	Cosmos-260	1968 115A	16.12.1968	3
765	USA	Intelsat-3B	1968 116A	19.12.1968	1
766	USSR	Cosmos-261	1968 117A	20.12.1968	25
767	USA	Apollo-8	1968 118A	21.12.1968	1
768	USSR	Cosmos-262	1968 119A	26.12.1968	1
769	USSR	Venyera-5	1969 01A	5.1.1969	2
770	USSR	Venyera-6	1969 02A	10.1.1969	2
771	USSR	Cosmos-263	1969 03A	12.1.1969	2
772	USSR	Soyuz-4	1969 04A	14.1.1969	1

Continued

Life time, days**	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
8	19.10.1968	65.4	89.9	205	362
11	22.10.1968	31.63	89.78	231	297
10 years	—	62.3	94.8	490	551
100 years	—	62.4	112.2	514	2177
100 years	—	99.00	101.39	797	855
3	28.10.1968	51.7	88.5	185	224
4	30.10.1968	51.67	88.6	205	225
40 years	—	74	95.3	523	556
18	18.11.1968	65	89.1	198	270
200 years	—	61.9	112.5	538	2172
20	23.11.1968	82.15	88.90	150	288
14	20.11.1968	106.0	89.73	130	390
		Heliocentric orbit			
10 years	—	32.87	97.78	378	940
7	17.11.1968		Moon fly-by and return		
5	18.11.1968	65.4	89.9	206	355
6 months	—	51.5	91.75	255	495
8	29.11.1968	65.4	89.8	203	350
8	7.12.1968	65.4	89.7	201	336
3000 years	—	74.06	109.3	1168	1234
91	5.3.1969	71	91.7	282	470
8	12.12.1968	106.24	93.30	136	736
	—	28.28	6750	418	223,440
500 years	—	35.00	100.16	765	778
8	18.12.1968	65	89.6	210	325
16	28.12.1968	81.02	88.67	169	248
6 months	—	48.5	100.3	219	1353
10,000 years	—	101.90	114.70	1410	1473
4.4. years	—	65	712	500	39,600
$> 10^6$ years	—	0.7	1436	35,770	35,790
54	12.2.1969	71	93.1	217	670
6	27.12.1968		Manned fly-by of the Moon		
6 months	—	48.5	95.2	263	818
131	16.5.1969		Soft landing on Venus		
127	17.5.1969		Soft landing on Venus		
8	20.1.1969	65.4	89.8	205	346
3	17.1.1969	51.67	88.25	173	225

Appendix 1

No.	Country	Name	Designation	Date launched (universal time)	Number of object units in orbit *
773	USSR	Soyuz-5	1969 05A	15.1.1969	2
774	USA	OSO-5	1969 06A	22.1.1969	1
775	USA	US Air Force	1969 07A	22.1.1969	1
776	USSR	Cosmos-264	1969 08A	23.1.1969	2
777	Canada–USA	Isis-1	1969 09A	30.1.1969	1
778	USA	US Air Force	1969 10B	5.2.1969	2
779	USA	Intelsat-3C	1969 11A	6.2.1969	1
780	USSR	Cosmos-265	1969 12A	7.2.1969	1
781	USA	Tacsatcom	1969 13A	9.2.1969	1
782	USA	Mariner-6	1969 14A	24.2.1969	1
783	USSR	Cosmos-266	1969 15A	25.2.1969	2
784	USA	ESSA-9	1969 16A	26.2.1969	3
785	USSR	Cosmos-267	1969 17A	26.2.1969	1
786	USA	Apollo-9	1969 18A	3.3.1969	3
787	USA	US Air Force	1969 19A	4.3.1969	—
788	USSR	Cosmos-268	1969 20A	5.3.1969	1
789	USSR	Cosmos-269	1969 21A	5.3.1969	4
790	USSR	Cosmos-270	1969 22A	6.3.1969	1
791	USSR	Cosmos-271	1969 23A	15.3.1969	1
792	USSR	Cosmos-272	1969 24A	17.3.1969	1
793	USA	OV-1-17	1969 25A	18.3.1969	—
		OV-1-18	1969 25B	18.3.1969	1
		OV-1-19	1969 25C	18.3.1969	1
		OV-1-17A	1969 25D	18.3.1969	
794	USA	US Air Force	1969 26A	19.3.1969	1
795	USSR	Cosmos-273	1969 27A	22.3.1969	1
796	USSR	Cosmos-274	1969 28A	24.3.1969	1
797	USSR	Meteor	1969 29A	26.3.1969	22
798	USA	Mariner 7	1969 30A	27.3.1969	1
799	USSR	Cosmos-275	1969 31A	28.3.1969	1
800	USSR	Cosmos-276	1969 32A	4.4.1969	1
801	USSR	Cosmos-277	1969 33A	4.4.1969	1
802	USSR	Cosmos-278	1969 34A	9.4.1969	1

* The object units in the orbit are assumed the last stage of launcher, fairings and other
** In case the time is counted not in day but in other units the latter are given after res-
*** Oct. 29, 1966, after the braking engine was disengaged, it fell to the Moon.

Continued

Life time, days **	Date of death (universal time)	Inclination of orbit to equator or to ecliptic, deg.	Period, min, (for heliocentric orbits, days)	Height of perigee, perihelion or perilune, km	Height of apogee, aphelion or apolune, km
3	18.1.1969	51.67	88.7	200	230
20 years	—	32.95	95.53	532	570
12	3.2.1969	106.15	97.04	142	1,090
13	5.2.1969	70	89.7	219	330
250 years	—	88.42	128.42	578	3,526
$>10^6$ years	—	80.41	114.22	1,396	1,441
$>10^6$ years	—	1.34	1436.4	35,782	35,808
~ 70	—	71	91.9	283	485
$>10^6$ years	—	0.65	1446.5	35,940	36,044
Heliocentric orbit					
8	5.3.1969	72.9	89.9	208	358
10^4 years	—	101.79	115.28	1,427	1,508
8	6.3.1969	65	89.9	210	346
10	13.3.1969	32.57	88.64	203	229
14	18.3.1969	92.00	90.50	134	461
1 year	—	48.4	109.2	219	2,186
20 years	—	74	95.3	526	558
6	12.3.1969	65.4	89.8	205	350
8	23.3.1969	65.4	89.7	200	342
3000 years	—	74	109.35	1,195	1,220
16 months	—	99.18	93.21	397	463
10 years	—	98.86	95.15	466	583
300 years	—	104.77	153.44	466	5,764
6	24.3.1969	99.10	89.37	175	309
4.3	24.3.1969	83.04	88.73	179	241
8	30.3.1969	65.4	89.9	205	356
8	1.4.1969	65	89.6	213	323
60 years	—	81.2	97.9	644	713
Heliocentric orbit					
14 months	—	71	95.2	284	805
8	12.4.1969	81.4	90.4	214	410
—	—	71	92	280	494
8	17.4.1969	65	89.7	203	338

elements.
pective figure.

Appendix II

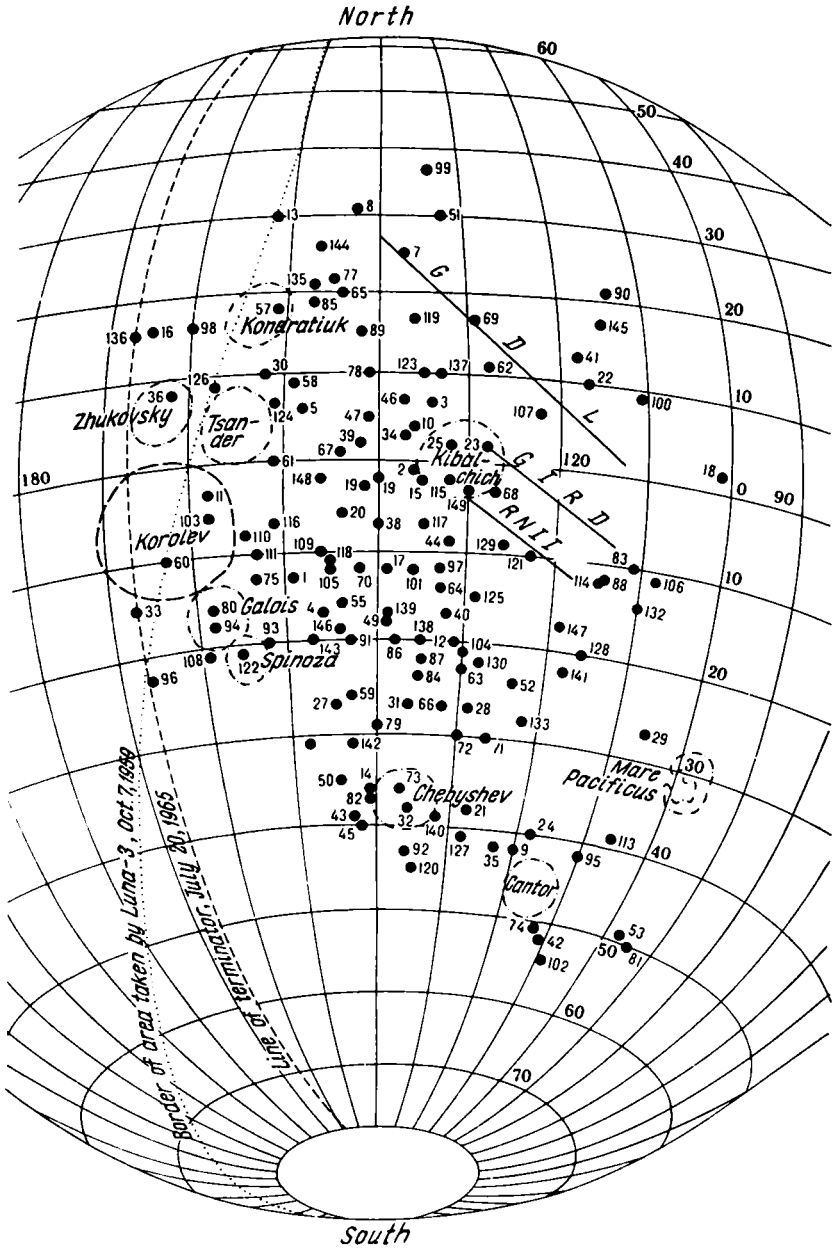
APPENDIX II

FORMATIONS ON THE FAR SIDE OF THE MOON AS PER PHOTOGRAPHS TAKEN BY LUNA-3

No.	Name	Coordinates	
		β_0	λ_0
1	Hertz	+11	+101
2	Giordano Bruno	+36	+103
3	Joliot-Curie	+25	+93
4	Jules Verne	−37	+151
5	Kurchatov	+32	+144
6	Lobachevsky	+9	+112
7	Lomonosov	+28	+99
8	Maxwell	+30	+99
9	Mendeleev	−2	+167
10	Pasteur	−10	+111
11	Popov	+14	+99
12	Sklodowska-Curie	−23	+102
13	Tsu Chung-chi	+18	+141
14	Tsiolkovsky	−22	+131
15	Edison	+24	+100
16	Mare Ingenii	−50	+179
17	Mare Moscoviense	+27	+149

DATA ON PERSONS WHOSE NAMES WERE GIVEN TO THE FORMATIONS ON THE FAR SIDE OF THE MOON AS PER PHOTOGRAPHS TAKEN BY LUNA-3

1. (2) Bruno, Giordano (1548—1600, Italy) — philosopher, astronomer.
2. (15) Edison, Thomas (1847—1931, USA) — electrician.
3. (1) Hertz, Heinrich (1857—1894, Germany) — physicist (electromagnetic wave theory).
4. (3) Joliot-Curie Frédéric (1900—1958, France) — physicist (artificial radioactivity).
5. (5) Kurchatov, I. V. (1903—1960, USSR) — physicist (nuclear physics).
6. (6) Lobachevsky, N. I. (1792—1856, Russia) — mathematician (non-euclidean geometry).
7. (7) Lomonosov, M. V. (1711—1765, Russia) — scientist-encyclopaedist.
8. (8) Maxwell, J. C. (1831—1879, UK) — physicist (electromagnetism, optics, molecular physics).
9. (9) Mendeleev, D. I. (1834—1907, Russia) — chemist (periodic law of elements).
10. (10) Pasteur, Louis (1822—1895, France) — microbiologist (vaccination against a number of infectious diseases, rabies).
11. (11) Popov, A. S. (1859—1905, Russia) — physicist (radio technology).
12. (12) Sklodowska-Curie, Marie (1867—1934, Poland) — physicist and chemist (investigation of radio-active elements).
13. (14) Tsiolkovsky, K. E. (1857—1935, USSR) — pioneer in astronautics and rocket technology.
14. (13) Tsu Chung-chi (5 century A. D., China) — mathematician and astronomer.
15. (4) Verne, Jules (1828—1905, France) — writer (science fiction).



Map of formations on the far side of the Moon as per list on pp. 574—578. The figures correspond to the names given in the list.

Appendix II

FORMATIONS ON THE FAR SIDE OF THE MOON AS PER PHOTOGRAPHS TAKEN BY ZOND-3

No.	Name	Coordinates		Object diameter (km)
		β_0	λ_0	
1	Abbe	−13.5	−149.0	35
2	Abbot	−1.5	−136.0	45
3	Abul Wefa	+7.0	−134.5	28
4	Avogadro	−17.0	−146.0	46
5	Al-Biruni	+6.0	−148.0	30
6	Andronov	−30.5	−147.5	30
7	Antoniadi	+25.0	−137.5	69
8	Arrhenius	+31.0	−143.0	52
9	Bhabha	−42.0	−119.5	35
10	Backlund	+4.0	−136.5	21
11	Bakhchivandzhi	−2.0	−159.0	66
12	Belopolsky	−19.5	−130.5	57
13	Blazhko	+30.5	−152.0	47
14	Bose	−36.0	−141.0	29
15	Bolyai	−2.0	−135.0	30
16	Bredikhin	+16.5	−165.5	70
17	Butlerov	−12.5	−138.5	83
18	Buffon	+2.5	−100.5	78
19	Fratres Vavilovi	−3.0	−141.5	102
		−2.5	−140.0	96
20	Van Gu	−6.0	−144.0	27
21	Van't Hoff	−38.5	−127.0	105
22	Wegener	+9.5	−117.0	80
23	Wien	+2.0	−128.0	48
24	Wiener	−39.5	−118.0	135
25	Wood	+2.0	−132.5	27
26	Galois	−16.0	−157.5	220
27	Helmert	−26.0	−145.0	51
28	Gerasimovich	−26.5	−128.5	65
29	Golitsyn	−27.0	−106.0	42
30	Graff	+10.0	−153.0	30
31	Jones	−27.0	−136.0	62
32	Dirichlet	−38.0	−136.0	25
33	Doppler	−15.0	−167.0	95
34	Dewar	+3.0	−136.5	36
35	Evdokimov	−42.5	−123.5	18
36	Zhiritsky	+8.5	−164.0	72
37	Zhukovsky	+7.0	−165.0	150
38	Zelinsky	−7.5	−139.0	30
39	Idelson	+2.0	−142.0	30

Continued

No.	Name	Coordinates		Object diameter (km)	Formations on Moon
		β_0	λ_0		
40	Ioffe	−16.5	−131.0	87	
41	Kamerlingh Onnes	+13.5	−118.0	61	
42	Cantor	−46.5	−116.0	117	
43	Carver	−39.0	−142.5	25	
44	Karpinsky	−9.5	−132.0	40	
45	Cassegrain	−42.0	−141.0	29	
46	Kekule	+6.5	−137.0	33	
47	Campbell	+4.0	−140.5	33	
48	Kibalchich	+0.0	−131.0	300	
49	Kimura	−18.0	−138.5	26	
50	Kleimenov	−35.5	−144.0	50	
51	Kovalevskaya	+30.5	−132.0	115	
52	Kovalski	−24.0	−124.0	30	
53	Kohlrausch	−49.0	−96.0	40	
54	Kondratiuk	+17.0	−153.0	170	
55	Confucius	−16.0	−143.0	120	
56	Korolev	−5.0	−164.0	460	
57	Kosberg	+18.0	−150.5	58	
58	Koch	+8.5	−149.0	65	
59	Krasovsky	−25.0	−143.0	51	
60	Krylow	−10.0	−164.0	60	
61	Langemak	+0.5	−151.0	108	
62	Langevin	+12.0	−127.5	51	
63	Larmor	−23.0	−130.5	25	
64	Lebedev	−14.0	−133.0	56	
65	Levi-Civita	+19.5	−144.0	31	
66	Lindblad	−26.5	−131.5	35	
67	Lowell	+1.0	−144.0	42	
68	Lodygin	−3.0	−127.0	21	
69	Lorentz	+17.0	−128.5	145	
70	Michelson	−12.0	−142.0	56	
71	Maksutov	−30.0	−126.0	26	
72	Mandelstam	−29.0	−130.5	34	
73	Mach	−36.0	−137.5	25	
74	Mendel	−51.5	−112.0	150	
75	Mechnikov	−13.0	−153.5	65	
76	Meshchersky	−43.5	−137.0	99	
77	Milanković	+22.0	−145.0	34	
78	Millikan	+10.0	−141.0	25	
79	Milne	−29.0	−140.5	40	
80	Minkowski	−16.0	−157.5	58	
81	Mozhaisky	−50.0	−93.0	30	

1/437—815

Continued

No.	Name	Coordinates		Object diameter (km)
		β^0	λ^0	
82	Moiseev	−37.0	−140.5	25
83	Morozov	−10.0	−110.5	30
84	Mohorovičić	−23.5	−135.0	77
85	Moulton	+19.0	−147.0	46
86	Nernst	−19.5	−137.0	40
87	Nöther	−22.0	−134.0	24
88	Neujmin	−12.5	−114.0	30
89	Nobel	+15.0	−141.5	95
90	Numerov	+21.0	−114.0	75
91	Obruchev	−20.0	−142.5	57
92	Orlov	−43.0	−136.0	22
93	Pavlov	−20.0	−151.5	62
94	Pannekoek	−17.5	−157.0	55
95	Papaleksi	−42.5	−109.5	26
96	Parenago	−23.0	−166.0	50
97	Pauli	−12.0	−133.0	106
98	Perelman	+16.5	−160.0	95
99	Perepelkin	+9.5	−157.5	50
100	Petropavlovsky	+36.0	−135.0	90
101	Petrushevsky	+8.0	−111.0	30
102	Pizzetti	−11.5	−136.0	71
103	Plaskett	−54.0	−109.0	45
104	Polzunov	−5.0	−159.0	39
105	Purkyně	−21.0	−129.0	54
106	Ramsay	−12.5	−144.5	25
107	Roche	−12.0	−107.5	41
108	Rynin	+6.0	−122.5	125
109	Saha	−21.0	−159.0	45
110	Sechenov	−9.5	−146.5	70
111	Sisakian	−8.0	−154.5	60
112	Smoluchowski	−9.5	−154.0	59
113	Spinoza	−21.0	−155.0	140
114	Steklov	−39.0	−105.0	28
115	Stoletov	−13.5	−115.0	35
116	Strömgren	−19.0	−143.5	87
117	Tesla	−2.0	−132.0	26
118	Timiriazev	−7.0	−151.5	60
119	Tyndall	−6.0	−134.0	30
120	Tikhov	−11.5	−145.5	45
121	Tikhomirov	+16.0	−136.0	125
122	Topchiev	−45.0	−134.0	23
123	Wells	−10.0	−123.0	68

Continued

No.	Name	Coordinates		Object diameter (km)
		β^0	λ^0	
124	Fowler	−21.0	−155.0	43
125	Fersman	+10.5	−135.0	22
126	Fizeau	+7.0	−152.0	60
127	Friedman	−14.5	−129.0	117
128	Khandrikov	−41.0	−128.0	20
129	Khvolson	−20.0	−116.0	40
130	Hayford	−9.5	−126.0	27
131	Hirayama	−22.5	−127.5	34
132	Tsander	+4.0	−155.0	210
133	Ceraski	−14.5	−110.0	35
134	Chaplygin	−27.5	−122.5	51
135	Chebyshev	−37.0	−136.0	190
136	Chandler	+21.0	−147.0	48
137	Chernyshov	+15.5	−167.5	75
138	Chzhan Khen	+10.5	−132.5	40
139	Shajn	−20.0	−134.0	51
140	Sharonov	−16.5	−138.5	29
141	Schwarzschild	−38.5	−132.0	91
142	Shi Shen	−22.0	−118.0	25
143	Schlesinger	−31.0	−142.5	60
144	Schmidt	−20.0	−147.0	46
145	Schrödinger	+26.0	−147.5	95
146	Sternberg	+17.0	−115.0	110
147	Shuleikin	−17.0	−119.0	20
148	Eötvös	−2.0	−146.0	70
149	Yablochkov	−2.5	−130.5	33
150	Mare Pacificus	−31.5	−98.5	180

No.	Name of crater chains	Coordinates, deg		Length, km
		beginning	end	
151	GDL (Gas Dynamics Laboratory)	+27.0	−140.5	1100
		+1.5	−113.0	
152	GIRD (Group for Study of Reactive Motion)	+2.5	−127.5	520
		−7.0	−114.0	
153	RNII (Rocket Research Institute)	−3.0	−132.0	540
		−12.0	−118.0	

Appendix II

DATA ON PERSONS AND ORGANIZATIONS WHOSE NAMES HAVE BEEN GIVEN TO FORMATIONS ON THE FAR SIDE OF THE MOON AS PER PHOTOGRAPHS TAKEN BY ZOND-3

(THE FIGURES IN BRACKETS ARE THOSE GIVEN IN THE MAP)

1. (1) Abbe, Ernst (1840—1905, Germany) — physicist (theory of microscope).
2. (2) Abbot, Charles (b. 1872, USA) — astrophysicist (solar physics).
3. (3) Abul Wefa (940—998, Korosan) — Arabian astronomer and mathematician.
4. (5) Al-Biruni (973—1048, Khorezm) — scientist-encyclopaedist.
5. (6) Andronov, A. A. (1901—1952, USSR) — physicist (theory of vibrations, theory of automatic control).
6. (7) Antoniadi, E. (1870—1944, France) — astronomer (investigation of planets).
7. (8) Arrhenius, S. (1859—1926, Sweden) — physicist-chemist (theory of electrical dissociation, works on astronomy and astrophysics).
8. (4) Avogadro, Amedeo (1776—1856, Italy) — physicist (Avogardo gas law).
9. (10) Backlund, O. A. (1846—1916, Russia) — astronomer (celestial mechanics).
10. (11) Bakhchivandzhi, G. Ya. (1909—1943, USSR) — test-pilot (testing of the first USSR jet plane).
11. (12) Belopolsky, A. A. (1854—1934, USSR) — astronomer (investigation of the revolution of the Sun, planets, Saturn's rings; determination of cosmic ray velocity).
12. (9) Bhabha Khomi (1909—1966, India) — nuclear physics.
13. (13) Blazhko, S. N. (1870—1956, USSR) — astronomer (variable stars).
14. (15) Bolyai, J. (1802—1860, Hungary) — mathematician (non-euclidean geometry).
15. (14) Bose, Dzahgadis (1858—1937, India) — physicist and physiologist.
16. (16) Bredikhin, F. A. (1831—1904, Russia) — astronomer (theory of comet forms, investigation of comets and meteors).
17. (18) Buffon, Georges (1707—1788, France) — naturalist.
18. (17) Butlerov, A. M. (1828—1886, Russia) — chemist (theory of structure of organic substances).
19. (47) Campbell, William (1862—1938, USA) — astronomer (investigation of planet atmospheres).
20. (42) Cantor, George (1845—1918, Germany) — mathematician (theory of infinite sets).
21. (43) Carver, George (1864—1943, USA) — agrobiologist.
22. (45) Cassegrain, N. (17th century, France) — physicist-optician (Cassegrain telescope system).
23. (133) Ceraski, V. K. (1849—1925, USSR) — astronomer (instrumental photometry).
24. (136) Chandler, S. (1846—1913, USA) — astronomer (motion of the Earth poles).
25. (134) Chaplygin, S. A. (1869—1942, USSR) — scientist in hydro- and aeromechanics.
26. (135) Chebyshev, P. L. (1821—1894, Russia) — mathematician, physicist (theory of numbers, theory of probability, theory of mechanisms).
27. (137) Chernyshov, N. G. (1906—1953 USSR) — chemist (rocket propellants).
28. (138) Chzhan Khen (78—139, China) — astronomer.
29. (55) Confucius (551—479 B. C., China) — philosopher.
30. (34) Dewar, James (1843—1923, UK) — physicist and chemist (method for measuring heat capacity at low temperatures).
31. (32) Dirichlet, Peter (1805—1859, Germany) — mathematician (theory of numbers).
32. (33) Doppler, Christian (1803—1853, Austria) — physicist and astronomer (Doppler effect).
33. (148) Eötvös, L. (1848—1919, Hungary) — geophysics and physics.
34. (35) Evdokimov, N. N. (1868—1940, USSR) — astrometry (determination of stellar parallaxes).
35. (125) Fersman, A. E. (1868—1945, USSR) — mineralogist and geochemist.
36. (126) Fizeau, Hippolyte (1819—1896, France) — physicist (physical optics).
37. (124) Fowler, Alfred (1868—1940, UK) — astrophysicist (stellar spectra).
38. (127) Friedman, A. A. (1888—1925, USSR) — geophysicist and mathematician (theory of turbulence, dynamic meteorology).

39. (26) Galois, Evariste (1811—1832, France) — mathematician (theory of groups).
40. (28) Gerasimovich, B. P. (1889—1937, USSR) — astronomer (astrophysics and astromechanics).
41. (29) Golitsyn, B. B. (1862—1916, Russia) — physicist (founder of seismology).
42. (30) Graff, Kazimir (1878—1950, Austria) — astronomer.
43. (130) Hayford, John (1868—1925, USA) — geodesist (Hayford Earth elipsoid).
44. (27) Helmert, Fridrich (1843—1917, Germany) — geodesist and gravimetrist (determination of the Earth dimensions).
45. (131) Hirayama, Kietsugu (Seidsi) (1874—1943, Japan) — astronomer.
46. (39) Idelson, N. I. (1885—1951, USSR) — astronomer and astronomy historian.
47. (40) Ioffe, A. F. (1880—1960, USSR) — physicist (physics of solids; semiconductors).
48. (31) Jones, Harold Spenser (1890—1960, UK) — astronomer.
49. (41) Kamerlingh Onnes, G. (1853—1926, Holland) — physicist (superconductivity).
50. (44) Karpinsky, A. P. (1847—1936, USSR) — geologist (geological structure, paleontology and minerals of European Russia).
51. (46) Kekule, Fridrich (1829—1896, Germany) — chemist (structural formulae).
52. (128) Khandrikov, M. F. (1837—1915, Russia) — astronomer and geodesist.
53. (129) Khvolson, O. D. (1852—1934, USSR) — physicist.
54. (48) Kibalchich, N. I. (1853—1881, Russia) — inventor in the field of rocket technology.
55. (49) Kimura, Khisasi (1870—1943, Japan) — astronomer.
56. (50) Kleimenov, I. T. (1898—1938, USSR) — specialist in rocket technology.
57. (58) Koch, Robert (1843—1910, Germany) — biologist (microbiology, tuberculosis pathogene).
58. (53) Kohlrausch, Friedrich (1840—1910, Germany) — physicist (electrical and magnetic measurements).
59. (54) Kondratiuk, Yu. V. (1897—1942, USSR) — scientist in the field of rocket technology.
60. (56) Korolev, S. P. (1906—1966, USSR) — rocket building.
61. (57) Kosberg, S. A. (1903—1965, USSR) — aircraft construction.
62. (52) Kovalski, M. A. (1821—1884, Russia) — astronomer.
63. (51) Kovalevskaya, S. V. (1850—1891, Russia) — mathematician (mathematical analysis, mechanics and astronomy).
64. (59) Krasovsky, F. N. (1878—1948, USSR) — geodesist (Krasovsky's elipsoid).
65. (60) Krylow, A. N. (1863—1945, USSR) — mechanic and mathematician (shipbuilding).
66. (68) Lodygin, A. N. (1847—1923, Russia) — electrical engineer (incandescent lamp).
67. (61) Langemak, G. E. (1898—1938, USSR) — rocket technology.
68. (62) Langevin, P. (1872—1946, France) — physicist (gas ionization, theory of para- and diamagnetism).
69. (63) Larmor, Joseph (1857—1942, UK) — physicist and mathematician (Larmor procession).
70. (64) Lebedev, P. N. (1866—1912, Russia) — physicist (light pressure).
71. (65) Levi-Civita, Tullio (1873—1941, Italy) — mathematician and mechanician (tensor analysis, celestial mechanics, hydrodynamics).
72. (66) Lindblad, Bertil (1895—1965, Sweden) — astronomer (dynamics of stellar systems).
73. (69) Lorentz, Hendrick (1853—1928, Holland) — physicist (theory of electronics).
74. (67) Lowell, P. (1855—1916, USA) — astronomer (investigation of planets).
75. (73) Mach, Ernst (1838—1916, Austria) — physicist (accoustics).
76. (71) Maksutov, D. D. (1896—1964, USSR) — specialist in astronomic optics (meniscus systems in optical instruments).
77. (72) Mandelstam, L. I. (1879—1944, USSR) — physicist (optics, radiophysics, theory of vibration).
78. (75) Mechnikov, I. I. (1845—1916, Russia) — physiologist (evolutive embryology, comparative pathology, microbiology and immunology).
79. (74) Mendel, George (1822—1884, Czechoslovakia) — naturalist (theory of heredity).
80. (76) Meshchersky, I. V. (1859—1935, USSR) — physicist (mechanics of variable mass solid bodies).

81. (70) Michelson, Albert (1852—1931, USA) — physicist (Michelson experiment).
82. (77) Milanković, M. (1879—1958, Yugoslavia) — mathematician, astronomer and geophysicist.
83. (78) Millikan, Robert (1868—1953, USA) — physicist (determination of electron charge and Plank constant; works on cosmic radiation and atom structure).
84. (79) Milne, Edward (1896—1950, UK) — astrophysicist (light energy transfer).
85. (80) Minkowski, Herman (1864—1909, Germany) — mathematician and physicist (geometrical interpretation of kinematics of special relativity theory).
86. (84) Mohorovičić, Andria (1857—1936, Yugoslavia) — geophysicist (seismology and meteorology).
87. (82) Moiseev, N. D. (1902—1955, USSR) — astronomer (celestial mechanics).
88. (83) Morozov, N. A. (1854—1946, USSR) — scientist in chemistry, astronomy. mathematics.
89. (85) Moulton, Forest (1872—1952, USA) — astronomy (celestial mechanics).
90. (81) Mozhaisky, A. F. (1825—1890, Russia) — inventor (aircraft construction).
91. (86) Nernst, Walter (1864—1951, Germany) — physicist and physicochemist (low temperatures, electrochemistry).
92. (88) Neujmin, G. N. (1885—1946, USSR) — astronomer (small planets and comets).
93. (89) Nobel, Alfred (1833—1896, Sweden) — chemist (production of explosives), founder of Nobel Prize.
94. (87) Nöther, Emmy (1882—1935, Germany) — mathematician (one of the founders of abstract algebra).
95. (90) Numerov, B. V. (1891—1943, USSR) — astronomer (astronometry, celestial mechanics and gravimetry).
96. (91) Obruchev, V. A. (1863—1956, USSR) — geologist and geographer (geology of mineral occurrences, geotectonics, geomorphology, etc., explorer of Siberia and Central Asia).
97. (92) Orlov, S. V. (1880—1957, USSR) — astronomer (astronomy of comets).
98. (94) Pannekoek, A. (1873—1960, Holland) — astronomer.
99. (95) Papaleksi, N. D. (1880—1947, USSR) — physicist (radiophysics and radio technology).
100. (96) Parenago, P. P. (1906—1960, USSR) — astronomer (variable stars).
101. (97) Pauli, W. (1900—1958, Switzerland) — physicist (quantum mechanics; Pauli principle.
102. (93) Pavlov, I. P. (1849—1936, USSR) — physiologist (higher nervous activity).
103. (98) Perelman, Ya. I. (1882—1942, USSR) — scientist and writer, science popularizer.
104. (99) Perepelkin, E. Ya. (1906—1940, USSR) — astronomer (solar physics).
105. (100) Petropavlovsky, B. S. (1898—1933, USSR) — rocket technology.
106. (101) Petrushevsky, F. F. (1828—1904, Russia) — physicist (electricity and electromagnetism).
107. (102) Pizzetti, Paolo (1860—1918, Italy) — astronomy, gravimetry, geodesy.
108. (103) Plaskett, John (1865—1941, Canada) — astronomy (astrospectrography).
109. (104) Polzunov, I. I. (1728—1766, Russia) — thermotechnician (steam engine).
110. (105) Purkyně, Jan (1787—1869, Czechoslovakia) — biologist (physiology).
111. (106) Ramsay, William (1852—1916, UK) — physicist and chemist.
112. (107) Roche, Edouard (1820—1883, France) — astronomer.
113. (108) Rynin, N. A. (1877—1942, USSR) — scientist in aeronautics, astronautics and descriptive geometry.
114. (109) Saha, Megnad (1893—1956, India) — astronomer and physicist.
115. (143) Schlesinger, Frank (1871—1943, USA) — astronomer (photoastronomy).
116. (144) Schmidt, O. Yu. (1891—1956, USSR) — astronomer, mathematician, geophysicist, Arctic explorer.
117. (145) Schrödinger, Erwin (1887—1961, Austria) — physicist (quantum mechanics).
118. (141) Schwarzschild, Karl (1873—1916, Germany) — astronomer (stellar photometry).
119. (110) Sechenov, I. M. (1829—1905, Russia) — physiologist (reflex theory of brain activity).
120. (139) Shain, G. A. (1892—1956, USSR) — astrophysicist (stellar spectroscopy and physics of gaseous nebulae).

121. (140) Sharonov, V. V. (1901—1964, USSR) — astronomer (investigation of planets and atmospheric optics).
122. (142) Shi Shen (4th century A. D., China) — astronomer (oldest known stellar catalogue).
123. (147) Shuleikin, M. V. (1884—1939, USSR) — radioengineer (method for calculation of antennas; receiving and transmitting devices; radio wave propagation).
124. (111) Sisakian, N. M. (1907—1966, USSR) — biochemist (ferments, space biology).
125. (112) Smoluchowski, Marian (1872—1917, Poland) — physicist (theory of fluctuations, kinetic theory of colloidal systems, critical opalescence).
126. (113) Spinoza, Benedict (1632—1677, Holland) — philosopher.
127. (114) Steklov, V. A. (1864—1926, USSR) — mathematician (mathematical physics, mathematical analysis, theory of elasticity, hydromechanics).
128. (146) Sternberg, P. K. (1865—1920, USSR) — astronomer (gravimetry and photoastronomy).
129. (115) Stoletov, A. G. (1839—1896, Russia) — physicist (photo effect).
130. (116) Strömgren, Ellis (1870—1947, Denmark) — astronomer.
131. (117) Tesla, Nikola (1856—1943, Yugoslavia) — electricial engineer.
132. (121) Tikhomirov, N. I. (1860—1930, USSR) — inventor of the smokeless powder rocket.
133. (120) Tikhov, G. A. (1875—1960, USSR) — astronomer (astro- and spectrophotometry, astrobotany).
134. (118) Timiriazev, K. A. (1843—1920, USSR) — botanist and physiologist (photosynthesis of plants).
135. (122) Topchiev, A. V. (1907—1962, USSR) — chemist (cathalytic transformation of hydrocarbons, chemistry of organic silicon compounds).
136. (132) Tsander, F. A. (1887—1933, USSR) — scientist in rocket technology.
137. (119) Tyndall, John (1820—1893, UK) — physicist and science popularizer.
138. (20) Van Gu (about 16th century, China) — according to legend he made the first manned rocket flight.
139. (21) Van't Hoff, Jackob (1852—1911, Holland) — chemist (physical chemistry and stereochemistry).
140. (19) Vavilov, N. I. (1887—1943, USSR) — biologist (works on origin of cultured plants and their immunity) — Vavilov, S. I. (1891—1951, USSR) — physicist and optician (luminiscence).
141. (22) Wegener, Alfred (1880—1930, Germany) — geophysicist (paleoclimatology, selenology, tectonics).
142. (123) Wells, Herbert (1866—1946, UK) — writer (science fiction).
143. (23) Wien, Wilhelm (1864—1928, Germany) — physicist (black body radiation law).
144. (24) Wiener, Norbert (1894—1964, USA) — mathematician, founder of cybernetics.
145. (25) Wood, Robert (1868—1955, USA) — physicist (optics, light resonance and resonance radiation).
146. (149) Yablochkov, P. N. (1847—1894, Russia) — electrical engineer (arc lamp —"electric candle").
147. (38) Zelinsky, N. D. (1861—1953, USSR) — chemist (organic cathalysis).
148. (36) Zhiritsky, G. S. (1893—1966, USSR) — combustion engineer (rocket technology).
149. (37) Zhukovsky, N. E. (1847—1921, USSR) — founder of modern hydro- and aeromechanics.
150. (151) GDL (Gas Dynamics Laboratory) — founded in the USSR in 1921. Developed the world's first electrical rocket engine (1929—33), first Soviet liquid-propellant engines (1930—33) and rockets firing wafered smokeless powder (1928—33). Stemming from the GDL was OKB, the Experimental Design Office for liquid-propellant engines, that designed the powerful engines of the geophysical and space rockets launched in the USSR in 1945—1969.
151. (152) GIRD (Group for Study of Reactive Motion) — founded in the USSR in 1932. Launched the first Soviet liquid-propellant rockets in 1933.
152. (153) RNII (Rocket Research Institute) — the world's first research institute for rocket engineering founded in USSR in 1933 on merger of GDL and GIRD. GDL, GIRD and RNII laid foundation of rocket engineering in the USSR.

Appendix II

FORMATIONS ON THE FAR SIDE OF THE MOON AS PER PHOTOGRAPHS TAKEN BY ZOND-3

(SUPPLEMENTARY LIST)

No.	Name	Coordinates		Object diameter (km)
		β_0	λ_0	
1	Aitken	+26.5	−156.0	52
2	Alekhin	+14.0	−149.0	34
3	Amici	+41.0	−146.5	78
4	Armiński	+12.5	−166.0	30
5	Artamonov	+27.0	−131.5	50
6	Artemyev	−57.5	−115.0	135
7	Bezout	−12.0	−152.0	70
8	Bellingshausen	+20.5	−141.0	75
9	Cyrano de Bergerac	+14.0	−157.5	55
10	Boyle	−29.0	−135.5	80
11	Bruce Ya.	−28.5	−145.5	162
12	Vanini	−16.0	−147.0	32
13	Vasilchenko	+36.0	−145.5	70
14	Weber	−28.5	−147.5	54
15	Vernadsky	−25.0	−137.0	75
16	Vetchinkin	−33.0	−140.0	100
17	Wilyev	+6.0	−160.0	39
18	Witkowski	−52.5	−134.5	46
19	Wittram	−56.0	−137.0	58
20	Voskresensky	+24.0	−130.5	55
21	Gavrilov	−1.5	−156.0	30
22	Ganswindt	+11.0	−157.5	74
23	Glasenapp	−56.5	−134.0	24
24	Grave	+24.5	−142.5	28
25	Grachev	+13.5	−147.5	31
26	Gregory	−72.0	−106.0	83
27	Green	−24.5	−145.0	55
28	D'Arsonval	−3.5	−150.5	35
29	Dedalus	−47.0	−130.5	96
30	Doellen	−55.5	−135.5	28
31	Drashusov	−30.5	−135.0	36
32	Drude	−29.5	−139.0	33
33	Zasyadko	−22.5	−145.5	120
34	Zsigmondy	+26.0	−152.0	35
35	Ibn Junus	−32.5	−144.0	37
36	Icarus	−49.5	−135.0	150
37	Ilyin	−3.0	−154.5	33
38	Curtis	−49.0	−118.5	56
39	Kleiber	−19.0	−126.0	80

Continued

No.	Name	Coordinates		Object diameter (km)
		β^0	λ^0	
40	Komarov	−25.0	−125.5	95
41	Comstock	−70.5	−192.5	80
42	Konoplev	+26.5	−130.0	90
43	Konstantinov	−16.0	−126.0	130
44	Kostinsky	−20.5	−136.5	74
45	Crookes	−31.0	−155.0	52
46	Kulik	−18.5	−134.0	57
47	Leucippus	−33.0	−146.0	34
48	Lenz	−50.0	−130.0	52
49	Litke (Lütke)	−5.0	−154.5	66
50	L'Hospital	+19.0	−159.0	50
51	Lundmark	+5.0	−167.0	53
52	Maly	−33.5	−154.5	32
53	Magnitsky	+20.0	−152.0	145
54	Mariotte	−28.0	−134.5	33
55	Möbius	+10.5	−108.0	45
56	Mezentsev	−31.5	−131.5	26
57	Morehouse	+24.0	−154.5	48
58	Perevoshchikov	+7.0	−160.0	48
59	Petrov	−33.5	−130.5	52
60	Pomortsev	+21.0	−129.5	42
61	Poincaré	+29.5	−144.5	120
62	Raspletin	−34.0	−155.5	29
63	Rastorguyev	−30.0	−133.0	82
64	Rozhdestvensky	−12.5	−156.0	28
65	Simonov	+32.0	−147.5	28
66	Simpson	−19.0	−143.0	44
67	Subbotin	−29.0	−149.5	39
68	Śniadecki	−7.5	−135.0	27
69	Wheatstone	+5.0	−162.0	70
70	Fedorov	+24.0	−161.0	100
71	Firsov	−33.5	−128.0	80
72	Fitzgerald	+41.5	−129.0	30
73	Khayyam	−66.5	−109.0	90
74	Harrito	−55.0	−112.5	35
75	Zinger	−53.0	−142.0	55
76	Charlier	+10.5	−110.5	35
77	Eyraud	−37.5	−147.5	25
78	Engelhardt	−18.5	−149.5	28
79	Gagarin	+49.0	−120.5	220
80	Landau	+17.0	−94.0	80
81	Razumov	+25.5	−120.0	95

Appendix II

DATA ON PERSONS WHOSE NAMES HAVE BEEN GIVEN TO FORMATIONS ON THE FAR SIDE OF THE MOON AS PER PHOTOGRAPHS TAKEN BY ZOND-3 (SUPPLEMENTARY LIST)

(THE FIGURES IN BRACKETS CORRESPOND TO THOSE IN THE LIST)

1. (1) Aitken, R. (1864—1951, USA) — astronomer (double stars).
2. (2) Alekhin, N. P. (1913—1964, USSR) — specialist in rocket technology.
3. (3) Amici, G. B. (1786—1863, Italy) — optician and botanist.
4. (4) Armiński, F. (1789—1848, Poland) — astronomer.
5. (5) Artamonov, N. N. (1906—1965, USSR) — specialist in rocket technology.
6. (6) Artemyev, V. A. (1885—1962, USSR) — specialist in rocket technology.
7. (8) Bellingshausen, F. F. (1779—1852, Russia) — seafarer (exploration of Antarctica).
8. (7) Bezout, E. (1730—1783, France) — mathematician (higher algebra).
9. (10) Boyle, R. (1627—1691, UK) — physicist and chemist.
10. (11) Bruce, Ya. V. (1670—1735), Russia) — statesman and military man; astronomer (Bruce calendar).
11. (76) Charlier, D. (1862—1934, Sweden) — astronomer (celestial mechanics and stellar statistics).
12. (41) Comstock, G. (1855—1934, USA) — astronomer (double stars).
13. (45) Crookes, W. (1832—1919, UK) — chemist and physicist.
14. (38) Curtis, H. (1872—1942, USA) — astronomer (comets and nebulae).
15. (9) Cyrano de Bergerac, S. (1619—1655, France) — writer.
16. (28) D'Arsonval, J. (1851—1940, France) — physiologist and physicist.
17. (29) Dedalus — a skilled mechanician, architect and sculptor, who, according to ancient Greek mythology, made the wings for himself and his son Icarus.
18. (30) Doellen, V. K. (1820—1897, Russia) — astronomer (practical astronomy).
19. (31) Drashusov, A. N. (1816—1890, Russia) — astronomer.
20. (32) Drude, P. (1863—1906, Germany) — physicist (optics, electronic theory, electromagnetic vibrations).
21. (78) Engelhardt, V. P. (1828—1915, Russia) — astronomer.
22. (77) Eyraud, A. (19th century, France) — writer (description of fantastic rocket flight to the Venus).
23. (70) Fedorov, A. P. (19th century, Russia) — rocket technology.
24. (71) Firsov, G. F. (1917—1960, USSR) — rocket technology.
25. (72) Fitzgerald, G. (1851—1901, Ireland) — physicist (electromagnetism).
26. (79) Gagarin, Yu. A. (1934—1968, USSR) — world's first spaceman.
27. (22) Ganswindt, H. (1856—1934, Germany) — inventor in the field of rocket technology.
28. (23) Glasenapp, S. P. (1848—1937, USSR) — astronomer (double and variable stars).
29. (25) Grachev, A. D. (1900—1964, URSS) — specialist in rocket technology.
30. (24) Grave, D. A. (1863—1939, USSR) — mathematician.
31. (21) Gavrilov, A. I. (1884—1955, USSR) — specialist in rocket technology.
32. (27) Green, G. (1793—1841, UK) — mathematician.
33. (26) Gregory, J. (1638—1675, UK) — mathematician and astronomer.
34. (74) Harriot, Th. (1560—1621, UK) — mathematician and astronomer.
35. (35) Ibn Junus (950—1009, Egypt) — astronomer (tables of motion of the Moon, the Sun and the planets).
36. (36) Icarus — the son of Dedalus who, according to ancient Greek mythology, flew up to the Sun on the wings made of feather and wax.
37. (37) Ilyin, N. Ya. (1901—1937, USSR) — specialist in rocket technology.
38. (73) Khayyam, Omar (1040—1123, Khorosan) — persian poet, mathematician and and astronomer.
39. (39) Kleiber, I. A. (1863—1892, Russia) — astronomer and mathematician (stellar statistics).
40. (40) Komarov, V. M. (1927—1967, USSR) — cosmonaut.
41. (42) Konoplev, B. M. (1912—1960, USSR) — specialist in rocket technology.

42. (43) Konstantinov, K. I. (1817—1871, Russia) — artillery, rocket technology and automatics.
43. (44) Kostinsky, S. K. (1867—1936, USSR) — astronomer (photoastronomy).
44. (46) Kulik, L. A. (1883—1942, USSR) — astronomer (meteorites).
45. (80) Landau, L. D. (1908—1967, USSR) — physicist.
46. (48) Lenz, E. Kh. (1804—1865, Russia) — physicist (electromagnetism).
47. (47) Leucippus (5th century B. C.) — ancient Greek philosopher.
48. (50) L'Hospital, G. (1661—1704, France) — mathematician (mathematical analysis).
49. (49) Litke (Lütke) F. P. (1797—1882, Russia) — seafarer and geographer.
50. (51) Lundmark, K. (1889—1959, Sweden) — astronomer.
51. (53) Magnitsky, L. E. (1669—1739, Russia) — mathematician.
52. (52) Maly, A. L. (1907—1961, USSR) — specialist in rocket technology.
53. (54) Mariotte, E. (1620—1684, France) —physicist (fluid and gas mechanics, optics).
54. (56) Mezentsev, Yu. B. (1929—1966, USSR) — specialist in rocket technology.
55. (57) Morehouse, D. (1876—1941, USA) — astronomer (comets).
56. (55) Möbius, A. (1790—1868, Germany) — geometrist.
57. (58) Perevoshchikov, D. M. (1788—1880, Russia) — astronomer and mathematician (celestial mechanics, analytic geometry).
58. (59) Petrov, E. S. (1900—1942, USSR) — specialist in rocket technology.
59. (61) Poincaré, H. (1854—1912, France) — mathematician physicist and phylosopher.
60. (60) Pomortsev, M. M. (1851—1916, Russia) — metheorologist and specialist in aeronautics and rocket technology.
61. (62) Raspletin, A. A. (1908—1967, USSR) — scientist in the field of radiotechnology and electronics.
62. (63) Rastorguyev, V. L. (1910—1945, USSR) — test-pilot of jet planes.
63. (81) Razumov, V. V. (1890—1967, USSR) — specialist in rocket technology.
64. (64) Rozhdestvensky, D. S. (1876—1940, USSR) — physicist-optician (anomalous dispersion, theory and system of atom spectra).
65. (65) Simonov, I. M. (1794—1855, Russia) — astronomer.
66. (66) Simpson, Thomas (1710—1761, UK) — mathematician.
67. (67) Subbotin, M. F. (1893—1966, USSR) — astronomer (celestial mechanics).
68. (68) Śniadecki, J. (1756—1830, Poland) — astronomer and enlightener.
69. (12) Vanini, L. (1585—1619, Italy) — phylosopher and astronomer.
70. (13) Vasilchenko, A. G. (1911—1961, USSR) — test pilot of jet planes.
71. (15) Vernadsky, V. I. (1863—1945, USSR) — mineralogist and geochemist (developed the fundamentals of geochemistry, biochemistry, radiogeology).
72. (16) Vetchinkin, V. P. (1888—1950, USSR) — scientist in aerodynamics.
73. (20) Voskresensky, L. A. (1913—1965, USSR) — specialist in rocket technology.
74. (14) Weber, W. (1804—1891, Germany) — physicist (electromagnetism).
75. (69) Wheatstone, Ch. (1802—1875, UK) — physicist.
76. (17) Wilyev, M. A. (1893—1919, Russia) — astronomer (theory of the Moon motion).
77. (18) Witkowski, V. V. (1856—1924, USSR) — geodesist.
78. (19) Wittram, F. F. (1854—1914, Russia) — astronomer and geodesist.
79. (33) Zasyadko, A. D. (1779—1837, Russia) — specialist in rocket technology.
80. (75) Zinger, N. Ya. (1842—1918, Russia) — astronomer and geodesist.
81. (34) Zsigmondy, R. (1865—1929, Austria) — chemist (chemistry of colloids).

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USA. *Aerospace*, Washington, published since 1963, quarterly. *Aerospace Medicine*, Washington, published since 1959, monthly (in 1930—59 was titled *Journal of Aviation Medicine*). *Aerospace Safety*, Washington, published since 1955, monthly. *AIAA Bulletin. American Institute of Aeronautics and Astronautics*, New York, published since 1964, monthly. *AIAA Journal*, New York, published since 1963, monthly (founded by merger of the *ARS Journal* and *Journal of the Aerospace Sciences*). *Air Force and Space Digest*, Washington, published since 1946, monthly (since 1918 was titled *Air Force*). *Air Force Space Digest International*, Washington, published since 1965, monthly. *American Astronautical Society Newsletters*, New York, published since 1962, bi-monthly. *APL Technical Digest*, Silver Spring, published since 1961, bi-monthly. *Astronautics and Aeronautics*, New York, published since 1957, monthly. *Aviation Week and Space Technology*, New York, published since 1960, weekly (in 1916—20 was titled *Aviation and Aeronautical Engineering*; in 1920—21, *Aviation and Aircraft Journal*; in 1922—47, *Aviation*; in 1947—59, *Aviation Week*). *Bioastronautics Report*, Washington, published since 1962, twice monthly. *Challenge*, General Electric's Missile and Space Division, Philadelphia, published since 1962, quarterly. *Cosmic Research*, New York, translation of the Soviet magazine *Kosmicheskiye Issledovaniya*, published since 1964, bi-monthly. *Current Contents of Space, Electronic and Physical Sciences*, Philadelphia, published since 1961, weekly. *Design News*, Englewood, published since 1946, bi-weekly. *International Aerospace Abstracts*, New York, published since 1961, twice a month. *Hydraulics and Pneumatics*, Cleveland, published since 1948, monthly. *Journal of Spacecraft and Rockets*, New York, published since 1964, monthly. *Journal of Astronautical Sciences*, Baltimore, published since 1954, bi-monthly. *Machine Design*, Cleveland, published since 1929, twice a month. *Mechanical Engineering*, New York, published since 1906, monthly. *Scientific and Technical Aerospace Reports* (*STAR*), Washington, published since 1963, twice a month (in 1958—62 was titled *U. S. National Aeronautics and Space Administration Technical Publications Announcements*). *Space—Aeronautics. The Magazine of Aerospace Technology*, New York, published since 1959, 13 issues a year (in 1943—58 was titled *Aviation Age*). *Space Age News*, Beverly Hills, Calif., published since 1958, monthly. *Space Journal*, Nashville, published since 1957, bi-monthly. *Space LOG*, Redondo Beach, published since 1960, quarterly. *Space Propulsion*, Washington, published since 1963, twice a month. *Space World*, Amherst, published since 1960, monthly. *Technology Week*, Washington, published since July, 1966, weekly (from 1956 to June, 1966, was titled *Missiles and Rockets*). *TNB. Technical News Bulletin*, Little Falls, N. J., published since 1957, quarterly. *U. F. O. Investigator*, Washington, published since 1957, bi-monthly. *Western Aerospace*, Los Angeles, published since 1925, monthly (incorporated the magazines *Western Aviation*, *Missiles and Space*, *Western Flying and Aerospace Briefing*). *World Space Directory*, Washington, published since 1963, twice a year.

USSR. *Astronavtika i raketodinamika*, series of *Ekspress-Informatsiya*, published since 1960, 48 times a year (in 1956—59 was titled *Raketnaya tekhnika*). *Astronomichesky zhurnal*, published since 1924, bi-monthly. *Astronomiya*, special edition of *Referativny zhurnal*, published since 1963, monthly (in 1953—62 was published as a cumulative edition titled *Astronomiya i geodeziya*). *Aviatsionnye i raketnye dvigateli*, special edition of *Referativny zhurnal*, published since 1963, monthly. *Aviatsiya i kosmonavtika*, published since 1962, monthly (in 1918—61 was titled *Vestnik vozdushnogo flota*). *Issledovaniye kosmicheskogo prostranstva*, special edition of *Referativny zhurnal*, published since 1964, monthly, branched from the *Astronomiya* special edition, see above. *Kosmicheskaya biologiya i meditsina*, published since 1967, bi-monthly. *Kosmicheskiye issledovaniya*, published since 1963, bi-monthly (in 1958—1963 was issued non-periodically and titled *Iskusstvennye sputniki Zemli*; 17 issues appeared). *Raketnaya tekhnika i kosmonavtika*, Russian translation of the *AIAA Journal*, published since 1961, monthly. *Raketostroyeniye*, special edition of *Referativny zhurnal*, published since 1962, monthly. *Tsiolkovskiye chteniya*, published since 1967, yearly. *Voprosy raketnoy tekhniki*, series of *Sbornik perevodov i obzorov inostrannoy periodicheskoy literatury*, published since 1951, monthly.

Yugoslavia. *Vasiona*, Belgrad, published since 1953, quarterly.

Classified List of Articles

1. COSMONAUTICS

Agreements on joint satellite launchings and space research
Aldrin E.
American Rocket Society
Anders W.
Armstrong N.
Astrobiology
Astrobotany
Astronaut
Astronautical conferences
Astronautics
Astronomical Council of the Academy of Sciences of the USSR

Belyayev P. I.
Beregovoy G. T.
Blagonravov A. A.
Borman F.
Braun W.
British Interplanetary Society
Bykovsky V. F.

Carpenter M. S.
Cernan E.
Chaffee R. B.
Clock paradox
Collins N.
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Cooper L. G.
Cosmonaut
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Cunningham R. W.
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Dyson's sphere

Eisele D.
Esnault-Pelterie R.
European Launcher Development Organization
European Organization for Space Research
Eurospace
Exobiology
Extraterrestrial civilization
Eyraud A.

Feoktistov K. P.
Fyodorov A. P.

Gagarin Yu. A.
Gagarin Medal
Galabert H.
Ganswindt G.
Gas Dynamics Laboratory
GDL
German interplanetary travel societies
Geshvend F.
GIRD
Glenn G.
Goddard R. H.
Goddard Medal
Gordon R.
Grissom V. I.
Group for Study of Reactive Motion

Hohman W.

International Academy of Astronautics
International Astronautical Federation
International Exhibition on Cosmonautics
International Geophysical Year
International Quiet Sun Year
Interplanetary travel
Interplanetary Travel Study Group
Interstellar communication

Khrunov Ye. V.
Kibalchich N. I.
Kleimenov I. T.
Komarov V. M.
Kondratyuk Yu. V.
Konstantinov K. I.
Korolev S. P.
Korolev Medal
Kramarov G. M.

Langemak G. E.
Leningrad Group for Study of Reactive Motion
Leonov A. A.
Life outside Earth
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Lovell J.

McDivitt J.
Meshchersky I. V.

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Moscow Group for Study of Reactive Motion
National Aeronautics and Space Administration
Nikolayev A. G.

Oberth H. J.
Oberth Medal
Orbita
OZMA project

Paradox of twins
Peenemünde
Perelman Ya. I.
Petropavlovsky B. S.
Pilot-Cosmonaut of the USSR
Popovich P. R.

Razumov V. V.
RNII
Rocket Research Institute
Roy L. M.
Rynin N. A.

Sänger E.
Schirra W.
Schweickart R.
Scott D. R.
Sedov L. I.
Shatalov V. A.
Shepard A. B.
Society for Studying Interplanetary Travel
Space
Space flight in legends and fiction
Spaceman
Spaceman's cockpit
Space philately
Space programme of France
Space programme of German Federal Republic
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Stafford T.
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Tereshkova V. N.
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Titov G. S.
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Valier M.
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Verne J.
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Victims of space flight
Volynov B. V.

White E.

Yegorov B. B.
Yeliseyev A. S.
Young J. W.

Zasyadko A. D.
Zhukovsky N. E.

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Propellant-loading station
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Classified articles

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Acclimatization
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Bacterial aeroplankton
Bioindicators
Biological effect
Biological rythms
Bionics
Biosphere
Biotelemetry
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Bradykinesia
Breathing apparatus

Cardiovascular system
Catapult
Centrifuge
Claustrophobia

Decalcification
Decompression sickness

Ejection
Ejection capsule
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Explosive decompression

g-load

Helium
High-altitude training
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Hypokinesia
Hypokinesic sickness
Hypotension
Hypoxia

Ionizing radiation doses
Isolation
Isolation chamber

Long-term acceleration

Medical data management system
Medical instrumentation
Medical monitoring
Motion sickness

Orientation of man in space

Parachute jump
Physiological investigation
Pressure chamber
Pressure suit

Radiation dose
Rotating room

Sealed cabin
Selection of spacemen
Sensory deprivation
Shock acceleration
Simulation
Simulation of year-long space flight

10. LIFE SUPPORT SYSTEMS

Classified articles

Activated carbon
Active sludge
Adsorber
Aeroponics
Aerotank
Air conditioning
Air desiccation
Air ionization
Allelopathy
Animal feeding
Asynchronous culture
Atmospheric moisture condensate
Autotrophs

Backpack
Biochemical composition of plants
Biocomplex
Biofilter
Biological air regeneration
Biological synthesis
Biological waste
Biomass
Biotechnical system

Cabin atmosphere
Cabin habitability
Carbon dioxide concentration
Catalytic oxidation
Chlorella
Closed biotechnical system
Coagulation
Condenser
Correcting nutrient solution
Correction of nutrient solution
Cultivation
Cultivation unit
Culture medium

De-odorization
Desorber
Dewar flask

Ecology
Ecological system
Electrodialisis
Evaporator

Food recycling
Freeze drying

Gas analyzer
Gasifier

Heterotrophic organisms
Humidity of air
Hydrolysis of urea
Hydrophilic materials
Hydrophobic materials
Hydroponics

Ion-exchange resins

Life support system
Life support system of *Apollo* spaceship
Life support system of spaceship
Life support system of *Vostok* spaceship
Liquid thermostatic control
Lithium chloride
Lithium hydroxide

Maximum permissible concentration
Metabolic water
Microorganisms
Mineral metabolism
Mineralization
Moisture separator

Nitrogen binding
Noxious contaminants
Nutrient solution
Nutrient solution regeneration

Ozonization
Oxygen generating substances
Oxygen, medical grade

Photoperiodism
Photosynthesis
Photosynthetic reactor
Physico-chemical mineralization
Population
Porous elements
Preservation of waste
Preservatives
Pressure control

Recycling of water
Recycling of substances
Regeneration controlling device

Sanitation unit
Saprophytes
Sorbents
Sorption
Space farm
Spaceman's hygiene

Classified articles

Spaceman's ration
Sterilization
Sublimation unit
Sulphur binding
Survival kit

Thermal oxidation
Transpiration moisture

Unicellular algae

Vegetation period
Ventilation

Water conditioning
Water electrolysis
Water regeneration
Water storage
Water supply
Wet oxidation

Yeasts

11. GEOPHYSICS

Accretion
Actinometric instrumentation
Altitude-frequency response
Antipode effect
Atmospherics
Atmospheric whistlers
Aurora

Dissipation

Earth albedo radiation
Earth radiation
Effective height
Escape cone
Exosphere

Geocorona
Geomagnetic disturbance
Geomagnetic trap
Geomagnetism

Heterosphere
Homosphere

Infrared instrumentation
Ionogram
Ionosonde
Ionosphere
Ionosphere sounding
Ionospheric reflection of radio waves

Lunar meteorological observatory

Magnetic storms
Magnetic trail
Magnetism of interplanetary space
Magnetism of planets
Magnetopause
Magnetosphere
Mesopause
Mesopeak
Mesosphere
Meteorological centre

Nephelometric analysis
Neutron albedo

Orbits of meteorological satellites

Quasineutral plasma

Radiation balance of Earth
Radiation belt of Earth
Radiation synoptics
Recurrent magnetic disturbances
Reverse problems of satellite meteorology

Scale height
Solar wind

Television equipment
Temperature of underlying surface
Terrestrial magnetism
Thermic sounding of atmosphere
Thermopause
Thermosphere
Troposphere
Turbopause

Upper atmosphere

Winds in ionosphere
Winds in upper atmosphere

Classified articles

Albedo
Altitude
Antimatter
Apex
Asteroids
Astrometry
Astronomical unit
Astronomy
Astrophysics
Autumnal equinox
Azimuth

Bolide

Celestial axis
Celestial coordinates
Celestial equator
Celestial meridian
Celestial poles
Celestial sphere
Comet
Cosmogony
Cosmology
Culmination

Day
Declination
Declination circle

Earth
Ecliptic
Elevation angle
Elongation
Ephemeris
Equation of time
Extragalactic astronomy

Forbush effect

Galactic nebulae
Galaxy
Gravimetry

Horizon
Hour angle

Interplanetary medium
Interplanetary space
Interstellar medium

Jupiter

Kordylewski clouds

Light year

Magnetic fields in space
Mars
Mercury, planet
Meridian circle
Metagalaxy
Meteor
Meteorites
Meteor stream
Milky way
Minor planets
Model atmospheres
Month
Moon

Nadir
Neptune

Parallel of declination
Parsec
Planet
Planetography
Planetoids
Planetology
Pluto
Prominence

Radiant
Radio astronomy
Radiotelescope
Right ascension

Satellites of planets
Saturn, planet
Second
Selenology
Sidereal period
Solar activity
Solar constant
Solar corona
Solar flares
Solar surges
Solar system
Solstice
Space vacuum
Spherical astronomy
Star clusters
Stars
Stellar astronomy
Stellar catalogues
Stellar magnitude

Classified articles

Sun
Sunspots
Synodic period

Telescope
Time
Transit (astronomical)
Transit (engineering)
Transit (of planets)

Universe
Uranus

Venus
Vernal equinox
Vertical circle

Year

Zenith
Zenith distance
Zodiac

13. SPACE LAW

Agreement

Legal status of celestial bodies
Liability for damage

Prevention of harmful space experiments

Rescue of spacemen and spaceships

Space law

Lates breakthroughs

A historic landing on the Moon and subsequent return to the Earth were performed by the crew of *Apollo-11*: Neil A. Armstrong, spacecraft commander, Michael Collins, *Command and Service Module* (*Columbia*) pilot, and Edwin E. Aldrin, Jr., *Lunar Excursion Module* (*Eagle*) pilot. The spacecraft was sent up by a *Saturn-5* from Launch Complex 39A at Cape Kennedy at 13 hr 32 min GMT, July 16, 1969. After twelve minutes of powered flight, the spaceship went into an almost circular geocentric orbit at an altitude of ~190 km and remained there for two and a half hours. Then the third stage engine operated for 5 min 47 s, accelerating the 44.6-ton spacecraft towards the Moon. The third stage received an impulse adequate for its injection into a heliocentric orbit. One trajectory correction was performed. After 76 hours of free flight, the retrorocket was operated for six minutes to bring *Apollo-11* into an initial selenocentric orbit with a perilune of 112 km and an apolune of 314 km.

The engine was restarted for 17 s at 21 h 44 min GMT, July 19, which reduced the perilune to 99.4 km and apolune to 121.5 km. It had been calculated that by the time the lunar descent operations began, the anomalies of the lunar gravitational field would cause this orbit to become circular at an altitude of 111 km.

N. Armstrong and E. Aldrin transferred into the *Lunar Excursion Module* (*LEM*) and at 17 hr 47 min divorced from the *Command and Service Module* (*CSM*), leaving it under the control of M. Collins. The two spacecraft spent 25 min in group flight at a distance of 12 to 25 m; M. Collins then operated the engine for several seconds to move his vehicle away. The retrorocket of the *LEM* was fired for 30 s, lowering the spaceship into an elliptical orbit whose least distance from the lunar surface was 15 km. At this point the *LEM* restarted its braking powerplant. Propellant reserve for ~2 min of hovering was provided to ensure selection of a landing site. N. Armstrong manually manoeuvred the spaceship over a large crater strewn with huge boulders and made a safe landing, raising clouds of dust, on July 20, at 20 hr 18 min GMT, on the Sun-lit surface of the Moon.

The landing site of the *Lunar Excursion Module* of the *Apollo-11* with N. Armstrong and E. Aldrin on board was in the south-western part of Mare Tranquillitatis, near the rim of a crater (0.799° N. Lat., 23.45° E. Long.). Looking out of the window several minutes after the landing, E. Aldrin described their surroundings as a collection of grey stones with quite a variety of shapes. Armstrong, also looking through a window, supplemented this description saying that the surface was comparatively flat with a multitude of craters 5 to 50 ft in diameter. They also saw a number of ridges 20 to 30 ft high, thousands of small craters 1 to 2 ft in diameter, angular blocks 2 ft in size, and a hill from one half to one mile away. On July 21, at 2 hr 56 min GMT, Neil Armstrong became the first man to set foot on the surface of the Moon. At 3 hr 16 min Edwin Aldrin joined him. The astronauts wearing spacesuits with portable life-support systems mastered walking, running and leaping on the lunar surface within 30 m from the *LEM*; they inspected

Latest breakthroughs

their vehicle; placed a TV camera on a tripod directing it towards the spacecraft; installed a seismograph; deployed a laser reflector permitting the Moon's distance from the Earth to be measured with high accuracy; unfolded a roll of aluminium foil for capturing particles of inert gases from solar wind; collected some 27 or 28 kg of lunar surface material; took photographs; held a telephone conversation with the Earth; installed a US flag; and left on the Moon medallions commemorating the spacemen who perished: R. Chaffee, Yu. Gagarin, V. Grissom, V. Komarov, and E. White. The first visitors to the Moon fastened a plaque to the descent stage of the *LEM*, standing in the Sea of Tranquillity on the Moon. The plaque bears the following inscription:

HERE MEN FROM THE PLANET EARTH
FIRST SET FOOT UPON THE MOON
JULY 1969, A.D.
WE CAME IN PEACE FOR ALL MANKIND

The plaque was signed by the three astronauts and President Nixon of the USA. Also left there was a magnetic record of good-will messages from 73 countries.

According to the first men on the Moon, N. Armstrong and E. Aldrin, the lunar surface is basically gray in colour, though it can acquire a brown shade depending on the Sun's height over the horizon. When collecting the samples of lunar soil, E. Aldrin found a piece of purple rock. The astronauts estimated the lunar rock to be porous and to have volcanic origin. The men's footprints were no deeper than 2.5 cm. The landing gear sank to a depth of 2.5 to 5 cm and the jet axhaust of the engine operated in landing made a 30-cm pit in the lunar soil.

The full duration of the astronaut's stay on the Moon was televised to the Earth. The code name of the landing site was Tranquillity Base. Aldrin returned to the cabin at 5 o'clock; ten minutes later Armstrong followed him. On leaving the Moon, besides scientific experiment and official souvenirs, the astronauts left their movie and TV cameras, tools for collecting lunar rock, and some of their garments. The astronauts had a meal and a rest, and at 17 hr 54 min GMT, July 21, after 21 hr 36 min on the Moon, blasted off. They docked the *Columbia CSM* at 21 hr 35 min, transferred into the latter, and jettisoned the *LEM*. Then, starting the main engine, they went into trans-Earth trajectory. On July 24, at 16 hr 50 min GMT, *Apollo-11* made a successful splash-down into the Pacific, near Johnston Island (southwest of Hawaii), some 17 km of the aircraft carrier *Hornet*. A helicopter lifted the spacecraft and the astronauts wearing bio-isolation suits to the ship. Here they transferred into a sealed caravan for a 21-day quarantine. The caravan was flown to Manned Space Flight Centre, Houston, Tex., and the astronauts entered an isolation box where they stayed until August 12. After perfectly completing this complex and unprecedented mission which required straining of all their abilities, the heroic crew returned to their native planet safe and sound.

A detailed investigation of the lunar soil samples brought to Earth by the crew of *Apollo-11* revealed no indication of life. However, it will

be possible to make a final conclusion only after exploration of the entire surface of the Moon and its sub-surface layer.

Latest breakthroughs

The moon dust was found to contain tiny glass globules which must have been responsible for the astronauts' complaints that it was slippery on the Moon. The glass globules are fractions of a millimeter in diameter, their colour is dark-brown, yellow or yellow-brown. Some pieces of glass are elliptical or cigar-shaped. The moon dust analyzed contained 1/4 to 1/3 glassy substance.

The substance covering the lunar surface consists of three sizes of particles: (1) fine powder (moon dust); (2) grains similar to bank sand in size; and (3) small fragments presumably of meteoric origin. It is believed that the moon dust coagulates under the effect of repeated impacts of small meteorites. The larger blocks of fine-grained substance thus formed make the lunar surface resemble loose soil. Many of the samples are rocks of volcanic origin that differ slightly in composition from effusive rocks found on the Earth. A considerable ammount of titanium oxide was established. The bulky pieces of rock revealed olivine minerals and feldspar containing some 49 wgt. % of fluorine.

Most of the rocks can be included in one of the following three classes: (1) pyrogenic, with inclusions of gas bubbles formed after cooling a lava-like substance; (2) bubbled rocks, also with gas-produced cavities, but with smaller bubbles; and (3) fragments presumably of meteoric substance or lava.

The USA have announced that they plan to send the *Apollo-12* spaceship carrying C. Conrad (command pilot), R. Gordon and A. Bean to land near the crater Copernicus. Conrad and Bean in two 3-hour periods of extravehicular activity are to perform a wider range of scientific investigations. Manned flights to the Moon are planned at intervals of 4 to 6 months. *Apollo-13* will be manned by J. Lovell (command pilot), T. Mattingly and F. Haise. The crew of *Apollo-14* will include A. Sheppard (command pilot), S. Roosa and E. Mitchell. *Apollo-13* is to land near the crater Fra Mauro, *Apollo-14* near the crater Sensorin, *Apollo-15* near the crater Littrow, *Apollo-16* on the slopes of the crater Tycho, *Apollo-17* on the hills at the crater Marius, *Apollo-18* in the valley near the crater Schröter, *Apollo-19* in one of the lunar "rivers", and *Apollo-20* (the last thus far planned) in the crater Copernicus.

In accordance with its programme of space exploration, the USSR sent up the automatic interplanetary station *Zond-7*. Its powerful launch vehicle roared off on August 8, 1969. The station's mission was carrying out further studies of the Moon and circumlunar space, colour photography of the Earth and the Moon from space at various distances, and further improvement of the modernized space-borne systems, subassemblies and structure of the space-rocket complex. The flight programme was similar to that of *Zond-6*. On August 11, the station flew past the Moon and, after completion of its mission, made a controlled re-entry into the Earth's atmosphere and an aerodynamically controlled descent. It softly landed in the preset region, south of Kustanai.

On February 24 and March 27, 1969, the automatic interplanetary stations *Mariner-6* and *Mariner-7* were sent on Mars fly-by missions from

Latest breakthroughs

Cape Kennedy. Their task was to explore the planet's surface and atmosphere. The two *Mariners* are similar in design and equipment: they are octahedral prisms whose height is 3.36 m, the span of the unfolded solar batteries is 5.8 m; the weight is ~413 kg. Each station carried a total of 1.93 m^2 of solar elements. A TV set transmitted pictures of Mars taken through red, green, blue, and yellow filters at a definition of 270 to 3000 m. *Mariner-6* and *Mariner-7* passed over the equatorial zone and South Pole of the planet on July 31 and August 5 at altitudes of ~3400 and ~3200 km, respectively.

During the fly-by, besides taking photos, the stations performed probing into martian atmosphere and surface by means of IR and UV spectrometers and IR radiometers, as well as radioprobing into the atmosphere.

The shots confirmed the results obtained by *Mariner-4*: martian surface abounds in craters similar to those on the Moon. The South Pole proved to have ruggedest terrain ever photographed on Mars. It is covered with craters and pits of every size. The marginal regions near the Pole are considerably broken due to the highly rugged surface. Other shots show desert regions free of pits and craters. Additional data have been gained to the effect that the polar snow covers consist of frozen carbon dioxide. Crater edges exhibit slight erosion. Martian surface temperature as measured by *Mariner-6* was +24° C on the Sun-lit side and down to —73°C on the dark side of the planet. No nitrogen was found in the atmosphere. The analyses revealed hydrogen and low concentrations of oxygen, carbon dioxide and carbon monoxide.

On October 11, 12 and 13, 1969, the Soviet Union first launched three spaceships on a group flight in a geocentric orbit. The seven men that crewed the vehicles were: G. S. Shonin, command pilot, and V. N. Kubasov, spaceship engineer, on board the *Soyuz-6*; A. V. Filipchenko, command pilot, V. N. Volkov, spaceship engineer, and V. V. Gorbatko, research engineer, on board the *Soyuz-7*; V. A. Shatalov, command pilot, and A. S. Yeliseyev, spaceship engineer, on board the *Soyuz-8*. The entire experiment lasted seven days, each spaceship staying in orbit for five days.

The flight mission included the following: checkout and flight-testing of spaceborne systems and of a modified structure of the *Soyuz* spaceships; further improvement of the control, orientation, and orbital stabilization systems and trial of spaceborne navigation aids; orbital manoeuvring of the spaceships relative to one another to debug the piloting systems; testing of a system for control of the simultaneous flght of three spaceships; scientific observations and photographing of geological-geographical objects on the Earth and exploration of its atmosphere; comprehensive studies in circumterrestrial space with the participation of three spaceships; experiments in engineering research, including testing of various methods of welding of a number of metals under space vacuum and weightlessness; biomedical investigations, and other experiments. Stable two-way radio-communications were maintained between the spaceships and the ground stations. TV reporting was broadcast from board the ships in flight.

After successful completion of their programmes, *Soyuz-6*, *Soyuz-7* and *Soyuz-8* landed near Karaganda on October 16, 17 and 18, 1969, respectively.

On October 4, 1957, Sputnik-1 heralded the beginning of the space era. Space flight has become a concomitant of our daily life; the interest in space exploration is universal. *The Soviet Encyclopedia of Space Flight* contains more than 1400 articles in all spheres of space flight and engineering. It provides the reader with authoritative information on space exploration.

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